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Un sommaire en français de ce rapport est inclus avant la table de matières.

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6. Abstract

Cargo handling operations in Arctic locations are hampered by extremes of weather, terrain and a lack of infrastructure. The Arktos amphibious vehicle has been successfully tried and tested in this environment: this project examines the design of an amphibious barge to work with the Arktos vehicle in northern situations.

The 12.5t payload cargo handling requirement is translated into a concept design which is confirmed by a series of model tests. The detail design is then developed into a prototype working specification. These stages are described in detail.

The initial prototype displayed some stability shortcomings, which when reviewed in depth produced a number of modifications that would improve the barge's operational characteristics to acceptable levels.

The modifications are described and it is recommended that any prototype built must incorporate them.

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16. Résumé

Le transfert de marchandise dans l'Arctique est entravée par les variations extrêmes du climat, les mauvais terrains et le manque d'infrastructures. Le véhicule Arktos amphibie a été testé avec succès dans cet environnement. Ce projet concerne la conception d'une barge amphibie adaptée au véhicule Arktos dans les régions nordiques.

La charge utile de 12,5 t mène à la conception d'un modèle plus tard validé par une série d'essais sur modèle. La conception détaillée mène plus tard aux spécifications d'un prototype opérationnel. Les étapes de la conception sont décrites en détail.

Le premier prototype présentait des faiblesses au niveau stabilité, qui lorsque revisées en détail menèrent à des modifications qui amélioreront les caractéristiques opérationnelles de la barge à un niveau acceptable.

Les modifications suggérées sont décrites, et il est recommandé de les incorporer dans les prochains prototypes.

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Executive Summary

Cargo handling in northern ports is hampered by the combination of hostile terrain, lack of facilities and/or infrastructure. Recent experience with Watercraft's Arktos amphibious vehicle has proven its ability to perform in Arctic conditions. This project develops the design of an amphibious barge to be used in conjunction with the Arktos vehicle.

The barge is designed to carry a 12.5 t payload and be able to traverse a variety of terrains, ice, water and ice/water interfaces. A conventional pontoon structure was chosen, with built up sides and ends to protect the cargo deck area. The aft end is a movable ramp to give access to the cargo deck area. Large diameter wheels (height adjustable) as well as a low friction sheathing on the bottom of the barge allow rolling or skidding options. A portable gantry is also provided to allow cargo handling self-sufficiency.

Model tests confirmed the basic stability, acceptable seakeeping characteristics and land manoeuvrability. The detailed design process demonstrated that the barge had some marginal stability characteristics and that the weight of the structure and fittings was higher than estimated. The barge as designed required the permanent attachment of the wheels to provide safety and stability margins.

A more detailed review of the barge stability resulted in an increase in the pontoon subdivisions to seven compartments from five and recommendations to fill buoyancy spaces with impervious material to reduce permeability, and to increase the barge depth by six inches to restore an acceptable freeboard. A prototype built to these specifications would have acceptable stability margins.

Sommaire

La manutention de marchandise dans les ports nordiques est entravée par la combinaison des mauvais terrains, le manque de services et/ou infrastructures. Des essais récents effectués avec le véhicule amphibie Arktos, manufacturé par Watercraft, ont prouvé qu'il pouvait opérer avec succès dans les conditions arctiques. Ce projet élabore la conception d'une barge amphibie pouvant être utilisée avec le véhicule Arktos.

La barge est conçue pour transporter une charge totale de 12,5 t ainsi que la capacité de franchir des terrains variés incluant les surfaces de glace, l'eau libre ainsi que l'interface eau/glace. La barge est essentiellement constituée d'un ponton sur lequel des côtés furent érigés pour protéger le pont de cargaison. La section verticale arrière est constituée d'une rampe mobile qui donne accès au pont de cargaison. Des roues à grand diamètre de hauteur ajustable, ainsi qu'un revêtement de fond à basse friction, permettent à la barge de se déplacer en glissant ou en roulant, au choix. Une structure porte-fûts amovible est fournie pour assurer la manutention indépendante de la cargaison.

Les essais de modèles ont confirmé la stabilité de base, un comportement en mer acceptable et une bonne maniabilité sur terre. La conception détaillée révéla que certaines characteristiques de stabilité de la barge sont marginales ainsi qu'un poids final excédant les estimations initiales. Une marge sécuritaire de stabilité ne put être rencontrée autrement que par la pause permanente des roues.

Une révision détaillée de la stabilité de la barge eut pour résultat l'augmentation du nombre de subdivisions du ponton de cinq à sept. Il fut recommandé de remplir les espaces de flottaison d'un matériel imperméable afin de réduire la perméabilité et augmenter la profondeur de la barge de six pouces afin d'obtenir un franc-bord acceptable. Un prototype construit selon ces spécifications aurait une marge de stabilité acceptable.

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1.0 Introduction

The problems of cargo handling in northern ports are particularly acute, especially where there are no conventional dock facilities or where the ice/water interface or other naturally occurring barriers exist to make cargo transfers between ship and shore difficult and potentially dangerous.

Studies by Canarctic Shipping Company Limited to define cargo handling needs in the North have concluded that, in many instances, a more efficient and environmentally sound method of moving cargo than currently employed is possible.

To this end, it was proposed that the tracked amphibious ARKTOS vehicle, developed by Watercraft Offshore Canada Ltd., towing a passive barge, has the potential to meet these cargo handling needs effectively and economically.

To test this potential, this Passive Amphibious Barge System (PABS) Project has developed a cargo handling performance specification into a fully costed specification for the production of a full size barge unit.

The project was carried out through a series of consequent tasks taking as a starting point a Performance Specification and developing it through concept design, model test and preliminary design to a fully costed Detailed Design.

2.0 Objectives

2.1 Project Objective

To produce a building specification for an ARKTOS PABS as an adjunct to the ARKTOS vehicle.

2.2 Specific Objectives

2.2.1 To develop a performance specification and conceptual design.

2.2.2 To carry out model tests to obtain full scale barge characteristics.

2.2.3 To develop a detailed design supported by working drawings and a building cost schedule.

3.0 Building Specification

3.1 Performance Specification

The barge is to be capable of carrying a payload of 12.5 t either containerised or loose, when towed behind an Arktos vehicle over a variety of terrains, ice, water and ice/water interfaces. The barge is to be fitted with a skid/wheel arrangement, interchangeable to suit the terrain being traversed. A cargo handling capability of a stern ramp and a portable lifting gantry is required to provide self sufficiency in remote locations.

Physical sizing of the barge is to match the towing vehicle in terms of resistance and manoeuvrability over land and water as well as following the vehicle track in broken ice. Speed of advance is to be about 20 km/hr over land and 5 knots in water.

A full listing of the performance criteria is given in Appendix I.

3.2 Conceptual Design

Preliminary estimates of leading dimensions were:

Length	38.25ft.
Beam	11.50ft.
Depth to Cargo deck	2.25ft.
Draught lightship	0.51ft.

Loaded displacement was estimated at 19.0 t being made up of barge (6.5 t); container (2.5 t) and cargo (10.0 t) at a draught of 1.75ft. and a freeboard of 6ins.

For traversing land and ice covered terrains large diameter wheels giving a minimum ground clearance of 6" were selected. Additionally, the bottom of the hull was to be sheathed in a low friction coefficient material to aid skidding. When afloat, the wheels would be clear of the water.

Stability calculations using Boeing's Ship Hull Characteristic Program (SHIPHUL) at 19.0 t displacement showed acceptable characteristics. The stability improving effects of the wheels at larger angles of heel were evident.

For the prototype, aluminum was selected as the material of construction and for strength margins a cargo weight of 20t is to be used. American Bureau of Shipping Rules and Regulations were applied as a guide to scantlings and selection of materials.

A series of model tests were proposed to test the validity of the conceptual design parameters.

Appendix I contains details of stability, other design considerations and model tests.

3.3 Model Tests

For test purposes a model scale of one fifth (1/5) was selected. The model was tested at Watercraft's Vancouver facility for overland behaviour and in the test tank of the University of British Columbia for resistance, seakeeping and stability characteristics.

3.3.1 Over Land (12.5 t payload configuration)

(i) The relative positions of the wheels were fixed to optimize turning capability without compromising forward rolling stability.

(ii) The towing resistance with wheels was about 20% of the resistance when skidded over prepared terrains, rising to 50% over natural terrains.

3.3.2 Over Water

For practical reasons a combination of displacements within the range 8 t and 28 t were chosen for the test runs. For a loaded displacement of 19 t, the towed resistance results in calm water predict that:

(i) the naked hull speed of advance will be about 4.25 knots;

(ii) the resistance of the barge with wheels lowered will be about 2.5 times greater than the resistance of the naked hull.

This indicates the magnitude of the penalty of operating with the wheels lowered and the need to be able to raise them clear of the water when under tow.

Directional stability was tested at the extremes of the displacement range at a speed of advance of 4 knots using BC

Research's compound towing frame technique. In both cases, behaviour was judged to be satisfactory.

Seakeeping was observed in the upper half of the displacement range. Both inshore and open water wave forms were used, and in both cases, pitch, roll and heave motions were considered normal and acceptable. Immersion of the wheels had a damping effect on motions. At the higher displacement there was a tendency to ship water onto the cargo deck.

3.3.3 Water/ice transitions

The barge was launched and retrieved over a simulated ice edge of various heights with both bow and stern leading, and at a number of angular attitudes to the ice edge. The upper half of the displacement range was selected with wheels up and wheels down. All entries and retrievals were judged to be acceptable, with a tendency to ship water being noted at the high displacements.

A full report on the model tests is in Appendix II.

3.4 Detailed Design

The amphibious barge consists of a rectanqular section (11.5ft. x 2.33ft.) pontoon about 36ft. long at the deck with ramped ends. Lightweight was calculated at 8.85 t giving a freeboard at the 12.5 t load condition of about at 2.6ins. The pontoon is sub-divided into seven compartments, each compartment being sealed by a hand hole. The bottom shell is sheathed with Ultra High Molecular Weight polyethylene. The ramped ends and sides are built up to about 5.5ft. to enclose the cargo deck area. The ramped aft end can be lowered and raised to provide access to the cargo deck area. When raised the aft ramp mates to the structure of the barge with a conventional heavy gasket type seal. The ramp is operated by a hand winch.

The wheels are mounted in towers and can be raised, lowered or locked in intermediate positions. A small diesel powered hydraulic power pack is provided for control of wheel position.

Towing points are arranged fore and aft: lifting eyes are provided as well as a number of cargo securing points. The cargo deck is strong enough to accept a 20 t payload either as a container or distributed.

A full description of the detail design plus working drawings are attached at Appendix III. An independent appraisal of the design by the Mariport Group raised a number of detail issues which were resolved by Watercraft. This interchange is attached at Appendix IV.

As designed, the amphibious barge was deemed to be capable of handling a 12.5 t payload over a range of terrains, through water and over ice/water interfaces with the wheels being permanently attached as an integral part of the structure.

3.5 Cost of Construction

The cost of constructing the barge as designed was estimated at about $149,215. This is made up of materials and fittings at $90,000 and a labour element of 143 man days at $59,215.

4.0 Conclusions

The passive amphibious barge as originally conceived by Watercraft, whilst sufficient for its intended purpose, has a number of undesirable practical features which must be investigated before any prototype is built.

These features are:

1. Low freeboard
2. Aft ramp seal of questionable integrity
3. Effects of retained loose water on the cargo deck
4. Extreme behaviour in the damaged condition.

5.0 Discussion

The features identified in the detailed design process which gave rise for practical concerns have been examined in depth. The findings are reported in the following paragraphs.

5.1 Barge Lightweight/Loaded Displacement

The barge lightweight or weight of structure and fittings was calculated at 8.85 t as compared to 6.5 t estimated, making the loaded displacement 21.35 t as compared to the 19.0 t predicted. This is partly due to underestimating but mainly due to selecting 20 t as the payload to increase the scantlings to provide a safety factor. In the absence of statutory or Class guidance on ice capable barges, the increased lightweight penalty is considered to be prudent and is therefore accepted.

5.2 Freeboard/Aft Ramp Seal

Due to the increased lightweight, salt water freeboard on even keel and without list is reduced to 2.6" (2.2" in fresh water). This places the aft ramp seal at the water line which is to be avoided as its watertight integrity cannot be assumed. The ramp seal therefore must be considered to have two effects:

(i) it is non-existent as far as buoyancy assumptions are concerned, and

(ii) it will retain loose water on the cargo deck.

5.3 Static and Dynamic Stability

Due to the change in lightweight, stability assumptions used in the design process are no longer valid. A complete stability review has been carried out and is documented at Appendix V. The main features are reproduced in the following paragraphs.

5.3.1 Static Stability

As a measure of static stability, Table 1 shows the comparison of GZ for the barge, barge with wheels and the ramp seal intact/not intact at the 12.5 t load condition.

Table 1: GZ max (ft.)

Seal	Naked barge	Barge & wheels up/down
Intact	0.80	1.60/2.30
Not intact	0.18	1.00/1.45*

*Estimated

5.3.2 Dynamic Stability

As a measure of dynamic stability, Table 2 shows the area under the GZ/heel angle curve for the barge with and without wheels, with and without an intact seal at the 12.5 t load.

Table 2: Area under GZ curve (ft.degrees)

Seal	Naked barge	Barge & Wheels in up position*
Intact	19	37
Not intact	4	14

*Operating position in open water

5.3.3 Free Surface Effects

The effects of water trapped on the cargo deck were calculated and show that initial GM will be negative and a heel of 7 degrees can be expected. With the low freeboard, this places the ramp seal partly under water.

The stability review clearly demonstrates the major role played by the wheels in preserving stability and enhancing dynamic behaviour. The requirement for them to be considered as a permanent part of the structure is therefore valid.

5.4 Damage Condition

The stability review at Appendix V also examined the effects of damage and in assessing the barge's ability to survive damage, there are two components to consider: reserve buoyancy and damage stability.

5.4.1 Reserve Buoyancy

Assuming 100% permeability, the seven compartment pontoon has sufficient reserve buoyancy to withstand a two compartment damage before sinking. With permeability less than 100%, the barge could survive the loss of a greater number of compartments.

5.4.2 Damage Stability

By inspection, the worst case damage will be either the bow or stern quarter compartment. Assuming 100% permeability, calculations show that in the 12.5 t load condition, without the seal and wheels, the barge will capsize with either compartment holed. With the wheels, the barge will loll (to a greater or lesser angle depending on the compartment holed) but not capsize: the damage water line with the aft quarter compartment flooded places the ramp seal well under water.

Changing the permeability of the damaged compartment improves the stability and attitude of the barge. Calculations show that at 25% permeability, with wheels and without seal, angles of loll are much reduced and listing and trimming due to stern quarter damage is almost eliminated. Calculations also confirm that for the same damage/permeability situation the barge without its wheels will result in a capsize.

Considering the intended use of the barge, damage should be assumed to be likely and measures to preserve barge integrity must be adopted.

5.5 Barge Depth

The very low freeboard is a matter of practical concern. Calculations were done to quantify the effects of increasing the barge depth. Results show that as the depth is increased the low angle stability increases but there is some loss of stability at higher angles.

In terms of the 12.5 t load condition statical stability, the GZ changes with increasing depth are shown in Table 3.

Table 3: GZ max. (ft.) - Ramp seal not intact

	Barge	Barge & Wheels Up
Datum	0.18	1.00
+4in	0.20	0.90
+8in	0.25	0.85
+12in	0.32	0.85

In terms of the 12.5 t load condition dynamic stability, the area under the GZ curve changes with increasing depth are shown in Table 4.

Table 4: Area under the GZ curve (ft. degrees) - Ramp seal not intact

	Barge	Barge & Wheels up
Datum	4.0	14.5
+4in	3.0	14.0
+8in	4.5	14.75
+12in	5.0	15.0

It is concluded that an increase in barge depth of 6ins. has no detrimental effects on the stability of the unit. The positive gain is an increase in the salt water freeboard to 8.6ins. which is more compatible with a barge depth of 2.8ft.

5.6 Gradeability

Refer to Appendix VI for grade (degrees)/speed (m.p.h.) curves. These calculations are based on torque and power characteristics of the Arktos towing vehicle assuming traction between the vehicle and the traversed surface exists. Clearly traction is not infinite but traction coefficients of three (3) have been measured for the vehicle which are considerably in excess of coefficients normally encountered between sliding surfaces.

These high coefficients are a function of the point design of the vehicle track and the limiting factor in traction will be the bulk strength of the material of the terrain being traversed rather than friction between the surfaces in contact.

An objective of the prototype testing program is to define the grade limits of the towing vehicle-towed barge combination.

6.0 Recommendations

6.1 Barge to be conspicuously marked:

LOAD NOT TO EXCEED 12.5 t WHEN OPERATING IN SALT WATER.

LOAD TO BE REDUCED TO 12.0 t WHEN OPERATING IN FRESH WATER.

WHEELS NOT TO BE REMOVED AT ANY TIME.

6.2 Barge depth to be increased by 6ins.

6.3 Barge pontoon watertight compartments to be filled with impervious material to reduce permeability to less than 25%.

6.4 During prototype testing, the effects of retained water on the cargo deck to be investigated. The fitting of freeing ports to be considered.

APPENDIX 1

Performance Specification, Concept Design and Model Test Program

Canarctic Shipping Company Limited
Extract from Design, Development and Testing
of the Arktos Passive Amphibious Barge System
Task #2
Sections 3.0, 4.0 and 5.0

3.0 Performance Specification

In agreeing the following performance parameters and concept design criteria, the towing capabilities of the CCG ARKTOS Beta vehicle were assumed.

3.1 Payload Requirements

(i) To be capable of carrying 12.5 tonnes as follows:
1-20′ x 8′ x 8′6" steel container loaded with 10 tonnes of homogeneous cargo or,
palletized goods or,
other break bulk cargo or,
drums of fuel oil or,
spray equipment (pumps, engines, etc.) approximately 7.5 tonnes + fuel or,
be used as an ATCO trailer office concept.

(ii) To possess a self loading/discharging capability.

3.2. Towing Requirements

(i) To be fully compatible with ARKTOS Beta regarding connecting mechanisms.

(ii) To be capable of being passively disconnected from the towing vehicle in an emergency.

3.3 Land Capability

(i) To be capable of traversing surface terrain by wheels or skids.

(ii) To embody a simple wheel/skid, skid/wheel interchange method.

(iii) To be capable of being backed up and safely moved downhill.

3.4 Marine Capability

(i) To be capable of functioning in typical sea and swell conditions.

(ii) To possess good handling characteristics with the wheels stowed in various positions.

3.5 Arctic Capability

(i) To be capable of functioning in typical ice and terrains encountered in Arctic re-supply operations.

(ii) To be capable of safe water/ice and ice/water transitions while under tow.

3.6 General Requirements

(i) To be capable of being safely handled by, and stowed, (and overstowed, if necessary), in or on a larger transportation vehicle.

(ii) To conform to all CCG statutory and Classification Society regulatory requirements as applicable.

(iii) To satisfy requirements for obtaining insurance at normal commercial rates.

3.7 General Arrangement

A preliminary outline arrangement is attached at Figure 1.1.

4.0 Concept Design

Having set the performance specification, details of the concept design were finalised as follows:

4.1 Payload Considerations

(i) All up Displacement 19.0 tonnes made up as follows:

Cargo	10.0t
Container	2.5t
Barge	6.5t

This all up displacement is limited by ARKTOS Beta's towing capabilities and notwithstanding this the barge structure is to be designed for a 20 tonne cargo weight in a 20ft container viz. an all up weight of 29 tonnes.

Leading dimensions:

Length	c. 11.66m
Beam	c. 3.51m
Depth	c. 1.68m
Draft	c. 0.51m

Speed of advance:

Land	20km/hr. (for seals and bearings)
Sea	5 knots

Ambient temperature (low limit) -
-50°C.

(ii) Cargo Handling

A stern ramp to be provided for moving cargo by wheeled loader or skids.

A gantry crane to be provided to handle single lifts e.g. a full 20ft. container. Crane to be easily assembled/disassembled.

4.2 Towing Considerations

(i) The towing arrangement to be a variable length cable with a towing winch of less capacity than the tractive effect of the ARKTOS Beta.

Winch particulars:

Spooling	9,400lbs.
Brake	23,000lbs.
Towing	30,000lbs.

A free spooling option to be provided to allow unpowered payout of the cable.

(ii) A weak link at the winch end of the towing cable to be provided for an emergency disconnect.

4.3 Land Performance

(i) Wheels to be the prime means of traversing and the towed unit must have a turning ability equal to the towing unit. Minimum ground clearance to be 0.15m. Base of the unit to be clad with Ultra High Molecular Weight (UHMW) Polyethylene to allow skidding over terrain and obstacles. One fifth (1/5) scale model tests to be carried out to confirm drag and turning characteristics.

(ii) Wheels to be raised/lowered/locked in position with a hydraulic power pack.

(iii) The towing vehicle to be fitted with a fabricated fender system around the towing winch to allow the barge to be close coupled when backing and going downhill.

4.4 Marine Performance

Existing concept calculations were accepted - see Figure 1.2 - but to be extended to:

(i) allow for the effects of retained water on the deck area at the higher angles of heel (assume barge fully loaded)

(ii) test the survivability of a fully loaded barge with its cargo retained in the capsize position by lashings.

One fifth (1/5) scale model tests to be carried out to confirm calculations of:

(i) resistance in open water

(ii) directional stability in open water

(iii) hydrostatic and dynamic stability.

Foam tyres to be used.

4.5 Arctic Performance

Existing concept calculations were accepted - see Figure 1.2 - but to be extended to demonstrate the behaviour of the unit at ice/water and water/ice transitions with varying degrees of list.

One fifth (1/5) scale model tests to be carried out to confirm behaviour in ice/water and water/ice transits.

Pneumatic tyres to be used.

4.6 General

(i) Strengthened lifting points to be provided for handling the complete unit in the loaded condition with cranes. Lashing points to be provided to allow the unit to be secured when being transported by sea. For the purposes of handling and stowing the unit, an all up weight of 29t. to be assumed. See 4.1 above.

(ii) Although CCG do not legislate for unmanned barges not carrying oil in integral tanks, they are to be consulted for safety and navigation implications. Unit to be designed to ABS regulations for steel barges, modified for aluminium.

(iii) Insurance cover to be investigated and reported in Task #3.

5.0 Model Test Program

Model tests to support the concept design were proposed as follows:

5.1 Overland

The following tests on land-interaction to be carried out with a one fifth (1/5) model at Watercraft's Vancouver facilities.

(i) Drag measurements in wheeled and sliding mode (model base to be coated with UHMW Polyethylene) over a number of representative soils.

(ii) Turning circle trials to fix wheel positions so that the turning characteristics of towing and towed units are compatible.

5.2 Overwater

The following tests to be carried out with a one-fifth (1/5) model in the towing tank at the University of British Columbia.

(i) Resistance in open water:
- hull only: wheels detached at displacements of 6.5, 13, 16, 19 and 29 tonnes at speeds of 2, 4, 5 and 6 knots. (20 runs in all)
- hull with wheels attached, fully lowered at displacements of 6.5, 16, and 29 tonnes either at speeds of 2, 3 and 4 knots or 4, 5 and 6 knots. (9 runs in all)
- hull with wheels attached at mid position at displacements of 6.5, 16 and 29 tonnes at speeds of either 2, 3 and 4 knots or 4, 5 and 6 knots (9 runs in all)

(ii) Directional Stability
- wheels fully lowered at displacements of 6.5 and 29 tonnes at a speed of 4 knots. (2 runs in all)
- wheels fully raised at displacements of 6.5 and 29 tonnes at a speed of 4 knots (2 runs in all)
- forward wheels raised and after wheels lowered at displacements of 6.5 and 29 tonnes at a speed of 4 knots (2 runs in all)

(iii) Stability
An inclining test at design Vertical Centre of Gravity (VCG) to be carried out to confirm calculations.

(iv) Seakeeping
Barge behaviour to be subjectively evaluated: motions to be videotaped. Due to tank size limitations, hull to be held stationary. Hull to be subjected to irregular wave

patterns from ahead and from the beam at displacements of 19 and 29 tonnes.

5.3 Arctic

The following tests to be carried out with a one-fifth (1/5) model in the towing tank at the University of British Columbia.

Water/ice and ice/water transits at various heights of "ice edge" to be simulated in the test tank.

Hull to be pulled back and forth over the "ice edge" at displacements of 19 and 29 tonnes to check the stability and freeboard calculations. Hull behaviour during transits to be photographed.

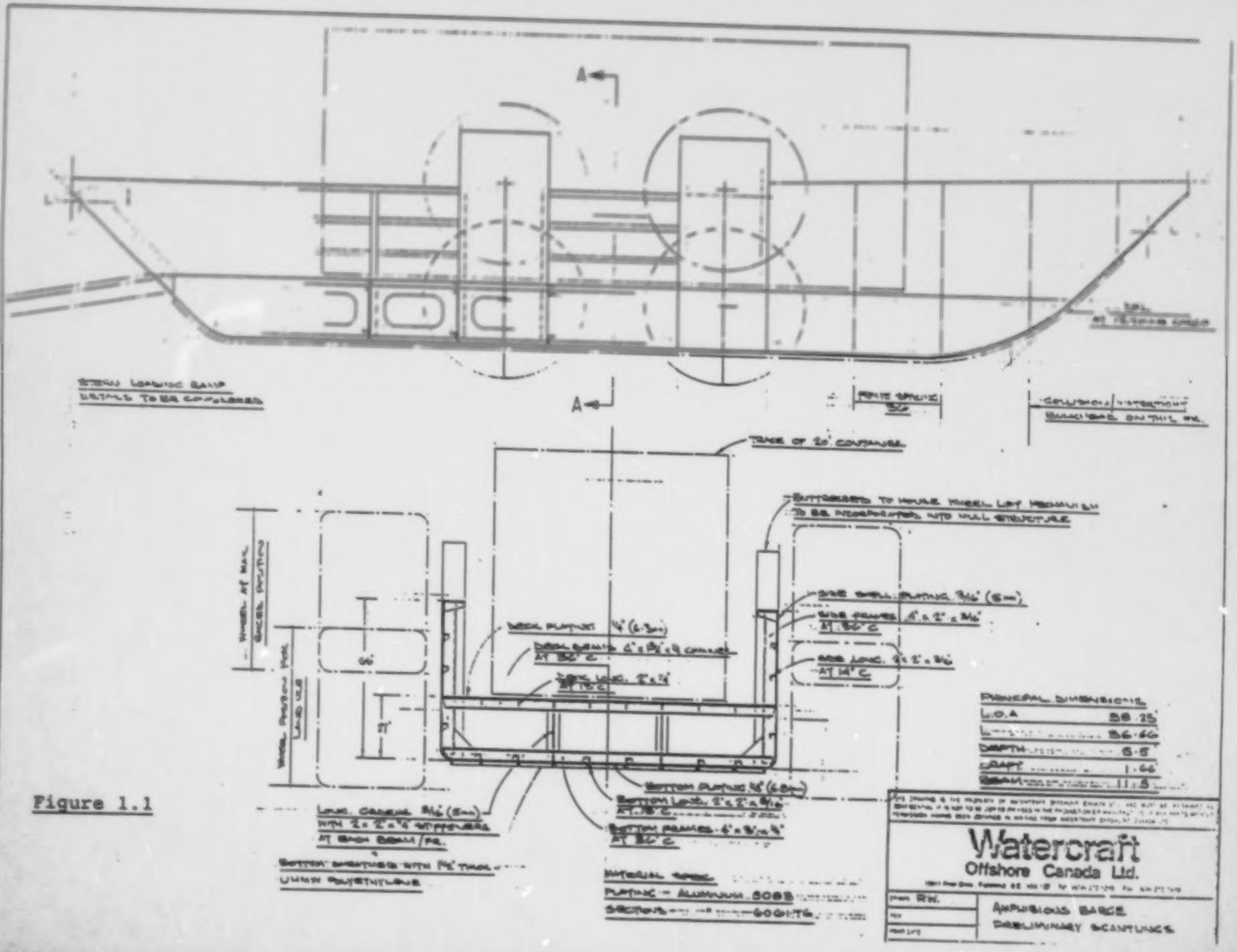

A
A
STERN LOADING RAMP
DETAILS TO BE CONSIDERED
FRAME SPACING
500
COLLISION / WATERTIGHT
BULKHEAD ON THIS FR.
TRACE OF 20' CONTAINER
BUTTRESSED TO HOUSE WHEEL LIFT MECHANISM
TO BE INCORPORATED INTO HULL STRUCTURE
WHEEL AT MAX.
RAISED POSITION
WHEEL POSITION FOR
LAND USE
66"
27"
DECK PLATING 1/4" (6.3mm)
DECK BEAMS 6" x 1 3/4" x 9 CHANNEL
AT 500 C
DECK LONG. 2" x 1/4"
AT 150 C
SIDE SHELL PLATING 3/16" (5mm)
SIDE FRAMES 4" x 2" x 3/16"
AT 500 C
SIDE LONG. 2" x 2" x 3/16"
AT 14" C
BOTTOM PLATING 1/4" (6.3mm)
BOTTOM LONG. 2" x 2" x 3/16"
AT 150 C
BOTTOM FRAMES 4" x 3" x 1/4"
AT 500 C
LONG. GIRDERS 3/16" (5mm)
WITH 2" x 2" x 1/4" STIFFENERS
AT EACH BEAM / FR.
BOTTOM SHEATHED WITH 1/2" THICK
UHMW POLYETHYLENE
MATERIAL SPEC.
PLATING - ALUMINUM 5086
SECTIONS - 6061-T6
PRINCIPAL DIMENSIONS
L.O.A 38.25
L 36.66
DEPTH 5.5
DRAFT 1.66
BEAM 11.5
Watercraft
Offshore Canada Ltd.
RW.
AMPHIBIOUS BARGE
PRELIMINARY SCANTLINGS

Figure 1.1

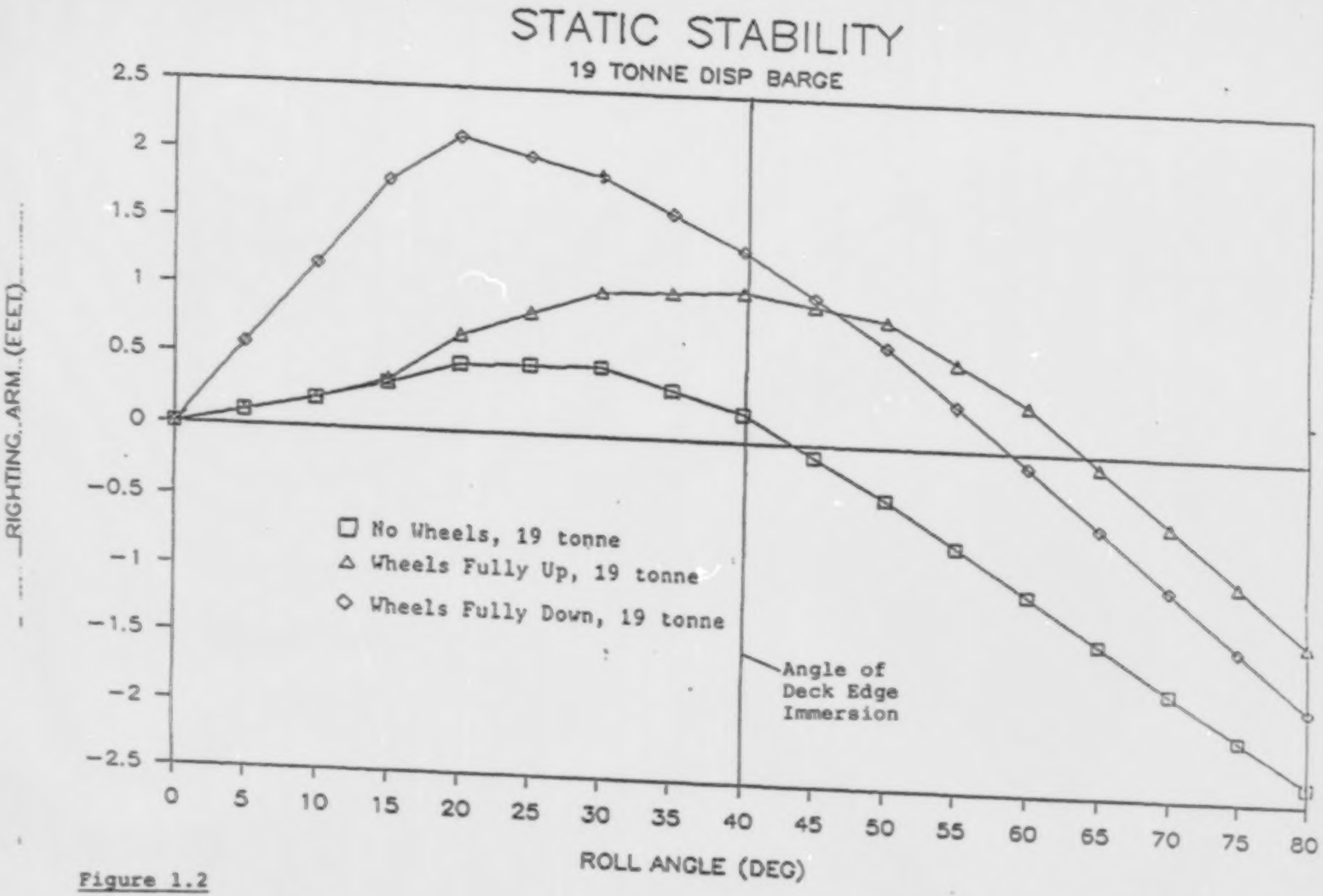

STATIC STABILITY
19 TONNE DISP BARGE
RIGHTING ARM (FEET)
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
ROLL ANGLE (DEG)
☐ No Wheels, 19 tonne
△ Wheels Fully Up, 19 tonne
◇ Wheels Fully Down, 19 tonne
Angle of Deck Edge Immersion

Figure 1.2

APPENDIX II

Model Tests and Preliminary Design

1. **Canarctic Shipping Company Limited**
Extract from Design, Development and Testing
of the Arktos Passive Amphibious Barge System
Task #3
Section 3.0 - Model Tests
Section 4.0 - Other Considerations

2. Watercraft Offshore Canada Ltd.
Passive Amphibious Barge Model Test Report

Attachment 1: Model Resistance Test Photographs
Attachment 2: Video Log
Attachment 3: Boeing "SHIPHUL" Computer Model

3.0 Model Tests

One fifth (1/5) scale model tests were carried out in the towing tank of BC Research between 11-13 July, 1990. The consolidated results of this program together with supporting calculations, pictures and video are contained in Watercraft's report at Attachment 1.

3.1 Overland (Task #2, 5.1)

All tests were done in the 12.5 tonne configuration.

(i) Towing resistance with wheels was approximately 20% of resistance when skidded over prepared terrains arising to 55% over natural terrains.

(ii) Relative positions of the fore and aft wheels were fixed by trial and error to optimize turning capability without compromising forward rolling stability. Turning moments measured for scantling design purposes.

3.2 Overwater (Task #2, 5.2)

For tank and model practical reasons these displacements were chosen:

8 tonne - lightship
16 and 28 tonne - anticipated operating conditions
19 tonne - data point between operating conditions

(i) Resistance in open water

A total of 42 calm water resistance tests were carried out.

- hull only, no appendages. Tests predict a barge towing speed of 4.25 knots at 16 tonne displacement.
- hull with wheels attached. Tests demonstrate the high resistance penalty of wheel immersion, confirming the need to raise the wheels clear of the water when transiting open water.

(ii) Directional Stability

Three tests were done, one without wheels at the extremes of the displacement range and one at full displacement with the after wheels lowered. The last condition was judged to be the worst condition for directional stability should it be present. In the three tests, directional stability was good so testing at intermediate points was curtailed.

A subjective evaluation of behaviour can be made by reference to the video.

(iii)Stability

Correlation of the computer prediction and model tests were within 9%. The computer model is therefore deemed to be accurate.

(iv) Seakeeping

The 16 and 28 tonne displacement conditions were tested in both inshore and open water conditions. Wheel positions were varied. A subjective evaluation of behaviour can be made by reference to the video.
In qualitative time, motions were considered normal with immersion of the wheels providing a dampening effect: no synchronisation with waves was observed. Some reservations were recorded in maintaining a dry barge in the 28 tonne condition.

3.3 Arctic (Task #2, 5.3)

The 16 and 28 tonne displacement conditions were launched and retrieved over two different heights of ice edge. A subjective evaluation of behaviour can be made by reference to the video.

The tests generally confirmed calculations: in the retrieve mode the stern did not immerse, see P108-4. In the launch mode slight immersion was noted in the 28 tonne condition.

4.0 Other Considerations

4.1 Effects of Retained Water on the Barge Deck (Task #2, 4.4)

Assuming watertight integrity intact:
- barge will float with deck completely flooded with wheels either up or down. See P108-5
- barge will return to upright position from 50° heel (deck edge immersion) with some water trapped on the deck: wheels assumed in the up position. See P108-6.

4.2 Capsize Survivability (Task #2, 4.4)

Assuming watertight integrity intact, barge will float upside down with 12 tonne container retained in place. See P108-7.

4.3 Lifting Arrangements (Task #2, 4.6(i))

Lifting arrangements to be limited to barge plus container up to 19 tonnes displacement and not 29 tonnes as required; because:

- the high safety factors at 29 tonnes demand unacceptably increased scantlings and weight penalties
- generally lifting capabilities at 29 tonne are not available.
- the 29 tonne factor is aimed at barge utilities, viz. wheels, ramp, etc. rather than payload.

4.4 CCG Requirements (Task #2, 4.6 (ii))

Restricted to navigational issues

4.5 Insurance (Task #2, 4.6 (iii))

The Mariport Group advise that for a prototype in the testing phase, a premium of about 5% of replacement cost will be required. This can be expected to reduce overtime and successful commercial usage to about 2½%.

Watercraft
Offshore Canada Ltd.

10611 River Drive,
Richmond, British Columbia
Canada V6X 1Z2

Tel: (604) 273-1299
Fax: (604) 270-7486

PASSIVE AMPHIBIOUS BARGE MODEL TEST REPORT

JULY 31, 1990

PASSIVE AMPHIBIOUS BARGE MODEL TEST PROGRAM RESULTS

EXECUTIVE SUMMARY

A one-fifth scale model of the amphibious barge was tested from July 11 - 13 at the Ocean Engineering Center at B.C. Research. The purpose of the test program was to determine the conceptual viability of towing the amphibious barge behind an ARKTOS vehicle. Tests done were: resistance; directional stability; inclining; seakeeping; and, water/ice transition simulation.

All tests proceeded as planned. Forty-two successful resistance tests were done in calm water. Resistance data are summarized in Graphs 1-4. It is predicted that the ARKTOS / Passive Amphibious Barge system will be able to carry a 12.5 tonne load through the water at about 4.25 knots.

Three directional stability tests were done in calm water. These tests were recorded on video tape.

Inclining of the barge was done with and without the wheels to confirm static stability prediction calculations.

Twenty-nine seakeeping conditions were tested. These tests were recorded on video tape.

A plywood step was constructed over the towing tank to simulate an ice transition. The barge was towed up onto the step, and pushed back into the water to confirm the buoyancy prediction calculations. These tests were video taped.

In addition, the barge was towed on different land conditions, both using the pneumatic tires, and skidded on UHMW. These tests allowed for the determination of the most desirable longitudinal placement of wheels, as well as an indication of the barge's overland characteristics.

In general, tests did not indicate that the barge had any undesirable characteristics. It was directionally stable in all conditions tested. The inclining and transitions tests confirmed the calculated predictions. Resistance was within limits of the towing capabilities of the ARKTOS in water.

RESISTANCE

A total of 42 calm water resistance runs were carried out, grouped as follows:

Group	Run #	Condition
A	1,2,3,4	8 Tonne Wheels Above Water
B	5,6,7,8,	16 Tonne Wheels Above Water
C	9,10,11,12	19 Tonne Wheels Above Water
D	13,14,15,16	28 Tonne Wheels Above Water
E	17,18,19,20	8 Tonne Wheels Down
F	21,22,23,24	16 Tonne Wheels Down
G	25,26,27	28 Tonne Wheels Down
H	28,29,30	8 Tonne Wheels Mid-way
I	31,32,33,34	16 Tonne Wheels Mid-way
J	35,36,37,38	28 Tonne Wheels Mid-way
K	39,40,41,42	8 Tonne with Axles without Wheels

The object of the resistance tests was to ascertain the resistance of the barge at various speeds, displacements and wheel heights. The speeds were chosen to be within the operational speeds of ARKTOS. The eight tonne displacement was tested as the model light ship condition, 16 tonne displacement as an anticipated nominal operating condition, 19 tonne displacement as the anticipated maximum design condition (representing a carried load of 12.5 tonnes), and 28 tonne displacement as a limiting case (representing a fully loaded 20 foot container carried on the barge). In each case the barge was ballasted for static level trim.

The model allowed for three wheel positions, down, mid-way and above water (or naked hull). The position of the center of the wheels (ie axle height), relative to the barge bottom were:

Condition	Model Axle Height (feet)	Full Scale Height (feet)
Down	0.349	1.75
Mid-Way	0.557	2.79
Upper	0.765	3.83

The model was attached to the towing carriage with the carriage's heave post. Model resistance, heave and trim data were acquired and recorded. All data processing was completed by B.C. Research standard methods.

The processed data from the resistance tests runs converted into full scale is contained in Table 1.

The processed data has also been plotted in graph form, see Graphs 1-4.

Photographs were taken of each run. A set of photographs are included as Appendix 1, presenting the group conditions from A-K at 5 Knots full scale speed.

RESISTANCE CONCLUSIONS

Graph 1 presents the "naked hull" barge, or the barge with no appendages such as wheels or axles. The curves are shaped as expected for a barge of this form. Plotted against these curves is the anticipated reserve thrust curve of ARKTOS. This predicts that ARKTOS should be able to tow the barge at the 16 tonne displacement at approximately 4.25 knots in calm water.

Graphs 2, 3, and 4 were generated to summarize the effects of the wheels on the barge at constant displacement. As expected, lowering the wheels into the water has a dramatic effect on the resistance of the barge. This can almost entirely be attributed to wave-making resistance. Due to the large beam of the model with the wheels on, B.C. Research felt that there may have been some tank edge effects which would make the resistance of the model appear to be slightly higher than that of the prototype full scale barge.

Waveforms can be observed in the photographs. It was noted that circulation within the inner diameter of the tire was present under certain tests. It is anticipated that this could be removed, and the resistance subsequently lowered, by covering over the rim of the wheel.

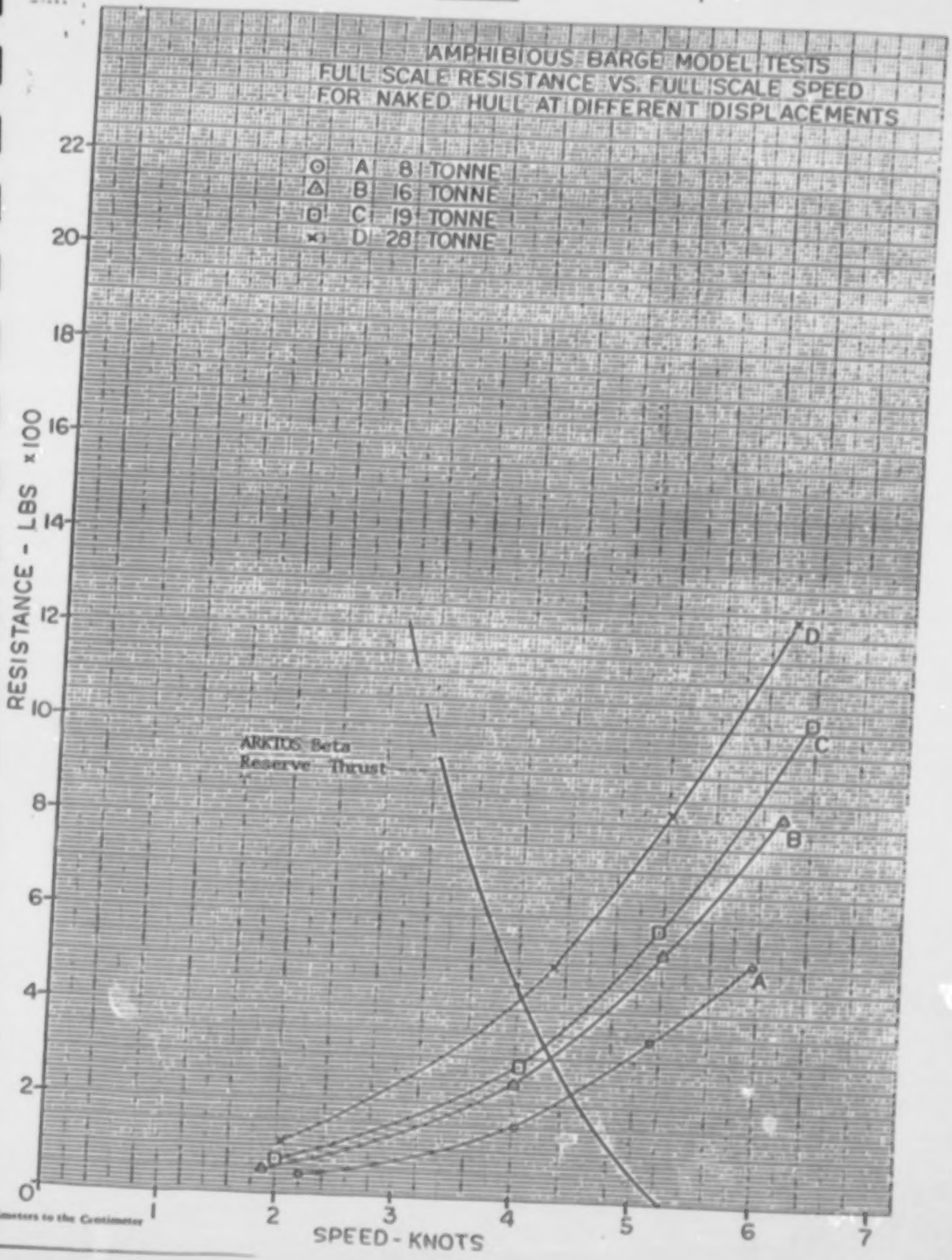
Obviously, the barge resistance is much less with the wheels out of the water than in. In the 16 tonne condition, 6 knots tests, the resistance of the barge with the wheels fully down was almost three times that of the same displacement barge with the wheels above water. The barge resistance is much less sensitive to displacement than wheel position. At six knots, the resistance of the naked hull barge at 28 tonnes was only 1.5 times that of the naked hull at 16 tonnes. This confirms the necessity of giving the barge the capability of raising the wheels out of the water. This will maximize the operating efficiency of the Passive Amphibious Barge System.

TABLE 1

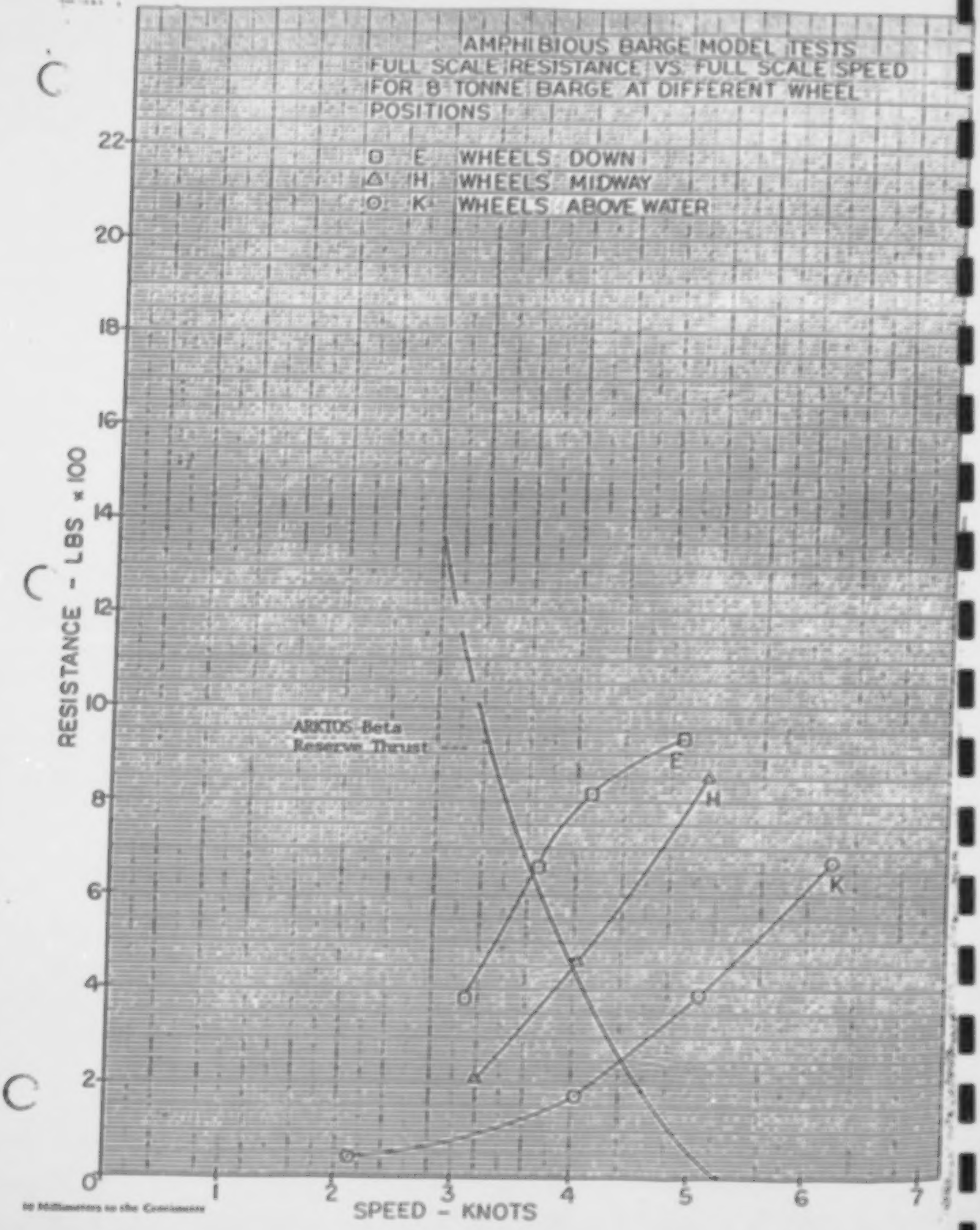
combined data

RUN NO.	SPEED (KNOTS)	V/(ROOTL) (KNOTS/ FT^0.5)	HEAVE CHANGE (INCH)	TRIM CHANGE (DEG.)	BASIC FRICT. RESIST. (LBS)	ROUGHNESS ALLOWANCE (LBS)	TOTAL FRICT. RESIST. (LBS)	RESIDUARY RESIST. (LBS)	TOTAL RESIST. (LBS)	RFRICT/ RTOTAL	RTOTAL/ DELTA (LBS/TON)	EHP	DESCRIPTI
1	2.19	0.415	-0.38	0.01	15.39	1.98	17.36	22.0	39.3	0.441	4.88	0.26	0T, NO WHEE
2	4.06	0.770	-0.75	0.02	47.64	6.81	54.45	109.9	164.3	0.331	20.39	2.05	0T, NO WHEELS
3	5.13	0.971	-1.46	0.06	72.99	10.84	83.83	262.0	345.8	0.242	42.92	5.44	0T, NO WHEELS
4	5.96	1.128	-1.96	0.08	96.13	14.63	110.76	394.1	504.9	0.219	62.66	9.23	0T, NO WHEEL
5	1.87	0.353	-0.26	-0.03	14.44	1.80	16.24	31.7	47.9	0.339	2.96	0.27	16T, NO WHEE
6	3.99	0.754	-1.16	-0.02	57.83	8.24	66.07	180.9	246.9	0.268	15.26	3.02	16T, NO WHEELS
7	5.18	0.978	-2.05	-0.02	93.25	13.88	107.13	415.9	523.0	0.205	32.32	8.30	16T, NO WHEE
8	6.16	1.164	-2.90	0.01	128.41	19.66	148.07	682.7	830.8	0.178	51.34	15.70	16T, NO WHEE
9	1.98	0.375	-0.50	0.04	17.21	2.17	19.38	49.9	69.3	0.280	3.61	0.42	19T, NO WHEELS
10	4.04	0.764	-1.09	-0.07	63.18	9.02	72.20	209.0	281.2	0.257	14.64	3.48	19T, NO WHEELS
11	5.17	0.978	-2.15	-0.01	99.37	14.78	114.15	462.1	576.3	0.198	30.00	9.14	19T, NO WHEE
12	6.37	1.207	-3.62	0.02	146.10	22.40	168.50	849.8	1018.4	0.166	53.01	19.91	19T, NO WHEELS
13	2.05	0.388	-0.36	0.11	21.37	2.71	24.08	83.1	107.2	0.225	5.00	0.67	20T, NO WHEELS
14	4.30	0.814	-1.66	-0.05	82.60	11.91	94.51	400.6	495.1	0.191	23.09	6.53	20T, NO WHEE
15	5.23	0.990	-2.44	0.06	118.29	17.62	135.91	682.9	818.9	0.166	38.19	13.13	20T, NO WHEE
16	6.20	1.174	-3.81	0.14	162.00	24.82	186.82	1050.5	1237.3	0.151	57.70	23.54	20T, NO WHEELS
17	3.10	0.587	-0.84	0.11	29.02	3.96	32.98	349.0	382.0	0.086	47.41	3.63	0T, WHEELS D
18	3.71	0.703	-1.34	0.12	40.35	5.68	46.03	616.9	662.9	0.069	82.27	7.55	0T, WHEELS D
19	4.89	0.926	-2.18	0.13	66.89	9.86	76.75	854.1	930.8	0.082	115.53	13.97	0T, WHEELS DOWN
20	4.12	0.780	-1.52	0.19	48.80	6.99	55.78	760.5	816.3	0.068	101.31	10.31	0T, WHEELS DOW
21	3.31	0.625	-1.19	0.13	41.09	5.67	46.76	587.3	634.1	0.074	39.18	6.44	16T, WHEELS
22	4.00	0.756	-2.03	0.26	58.14	8.29	66.43	929.2	995.7	0.067	61.52	12.22	16T, WHEELS DOWN
23	5.13	0.969	-3.19	0.28	91.73	13.63	105.36	1388.6	1493.9	0.071	92.31	23.51	16T, WHEELS DOWN
24	5.94	1.123	-4.40	0.61	120.24	18.30	138.54	2078.0	2216.5	0.063	136.96	40.41	16T, WHEELS
25	3.09	0.586	-1.31	0.26	45.26	6.17	51.43	700.2	751.6	0.068	35.05	7.13	20T, WHEELS D
26	4.15	0.786	-2.53	0.33	77.47	11.11	88.57	1341.9	1430.5	0.062	66.71	18.21	20T, WHEELS DOWN
27	5.17	0.979	-4.10	0.51	116.03	17.25	133.28	2026.6	2159.8	0.062	100.73	34.27	20T, WHEELS D
28	3.20	0.605	-0.96	0.00	30.71	4.21	34.92	174.5	209.4	0.167	25.99	2.05	0T, WHEELS MI
29	4.06	0.769	-1.37	0.01	47.52	6.79	54.31	405.9	460.2	0.118	57.12	5.73	0T, WHEELS MID
30	5.12	0.969	-2.45	0.03	72.73	10.80	83.53	766.9	850.4	0.098	105.55	13.36	0T, WHEELS MID
31	3.13	0.592	-1.02	0.14	37.20	5.09	42.29	318.8	361.1	0.117	22.31	3.47	16T, WHEELS M
32	4.07	0.769	-2.19	0.22	60.03	8.58	68.61	733.8	802.4	0.086	49.58	10.02	16T, WHEELS M
33	5.12	0.967	-2.98	0.10	91.41	13.58	104.99	987.8	1092.7	0.096	67.52	17.16	16T, WHEELS MID
34	6.22	1.176	-4.47	0.38	130.84	20.07	150.91	1698.4	1849.3	0.082	114.27	35.30	16T, WHEELS M
35	3.11	0.589	-1.31	0.10	45.69	6.24	51.93	555.1	607.1	0.086	28.31	5.79	20T, WHEELS M
36	4.15	0.786	-2.46	0.43	77.46	11.10	88.56	1065.0	1153.5	0.077	53.00	14.68	20T, WHEELS MID
37	5.13	0.972	-3.54	0.52	114.43	16.99	131.42	1498.8	1630.2	0.081	76.03	25.67	20T, WHEELS M
38	5.95	1.126	-4.88	0.69	149.88	22.80	172.68	2102.4	2275.1	0.076	106.10	41.50	20T, WHEELS M
39	2.12	0.401	-0.28	-0.01	15.46	1.97	17.44	29.0	46.5	0.375	4.58	0.30	0T, AIL W/O WHEEL
40	4.04	0.764	-0.93	-0.05	50.27	7.17	57.44	119.1	176.5	0.325	17.39	2.19	0T, AIL W/O WHEE
41	5.08	0.963	-1.74	-0.01	76.72	11.38	88.10	301.1	389.2	0.226	38.34	6.07	0T, AIL W/O W
42	6.19	1.171	-2.62	0.09	110.02	16.85	126.87	544.4	671.2	0.189	66.13	12.74	0T, AIL W/O W

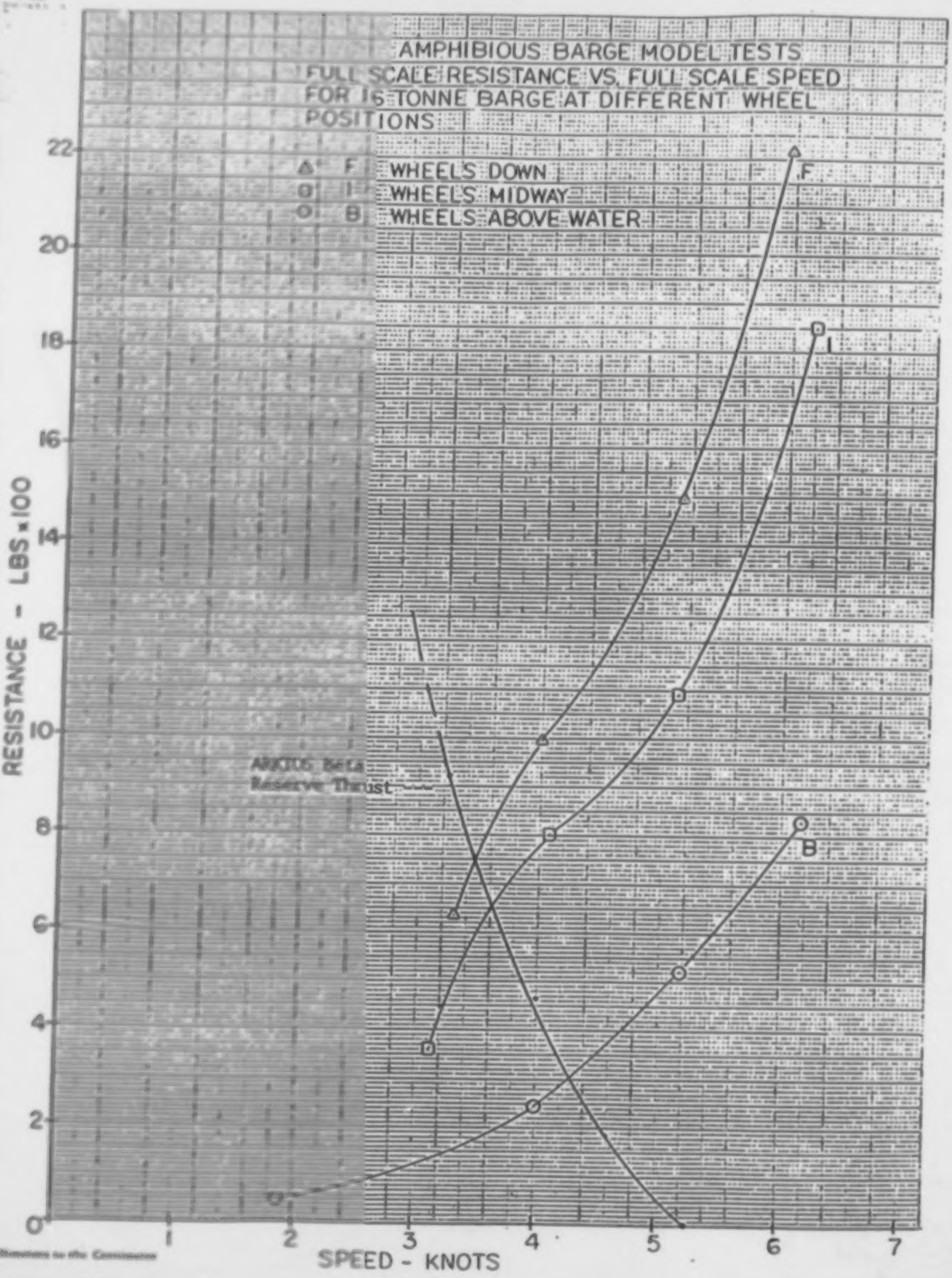
GRAPH 1


AMPHIBIOUS BARGE MODEL TESTS
FULL SCALE RESISTANCE VS. FULL SCALE SPEED
FOR NAKED HULL AT DIFFERENT DISPLACEMENTS
○ A 8 TONNE
△ B 16 TONNE
□ C 19 TONNE
× D 28 TONNE
ARKTOS Beta
Reserve Thrust
A
B
C
D
RESISTANCE - LBS ×100
0
2
4
6
8
10
12
14
16
18
20
22
1
2
3
4
5
6
7
SPEED - KNOTS
Millimeters to the Centimeter

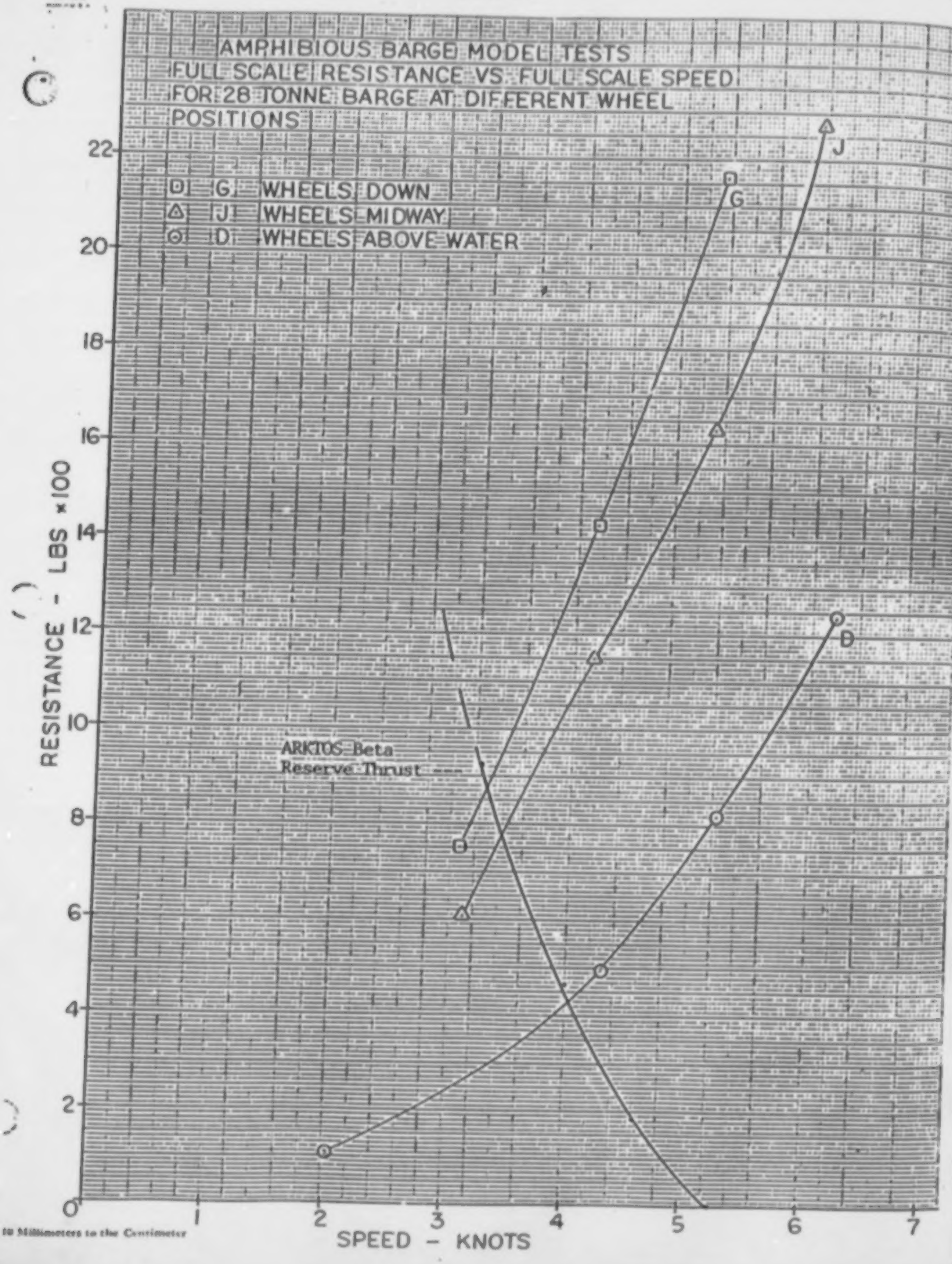
GRAPH 2


AMPHIBIOUS BARGE MODEL TESTS
FULL SCALE RESISTANCE VS. FULL SCALE SPEED
FOR 8 TONNE BARGE AT DIFFERENT WHEEL POSITIONS
□ E WHEELS DOWN
△ H WHEELS MIDWAY
○ K WHEELS ABOVE WATER
ARKTOS Beta Reserve Thrust
E
H
K
RESISTANCE - LBS × 100
0
2
4
6
8
10
12
14
16
18
20
22
SPEED - KNOTS
1
2
3
4
5
6
7
10 Millimeters to the Centimeter

GRAPH 5


AMPHIBIOUS BARGE MODEL TESTS
FULL SCALE RESISTANCE VS. FULL SCALE SPEED FOR 16 TONNE BARGE AT DIFFERENT WHEEL POSITIONS
△ F WHEELS DOWN
□ I WHEELS MIDWAY
○ B WHEELS ABOVE WATER
F
I
B
ARKTOS Beta
Reserve Thrust
RESISTANCE - LBS x 100
0
2
4
6
8
10
12
14
16
18
20
22
SPEED - KNOTS
1
2
3
4
5
6
7

GRAPH 4



10 Millimeters to the Centimeter

DIRECTIONAL STABILITY

B.C. Research has developed a standard for evaluating directional stability of a towed vessel. The main carriage is used as the towing vessel. A secondary carriage, linked to the main carriage, holds the towed vessel in an offset position until the required speed is reached. The towed vessel is then released from the secondary carriage to be free on the end of the tow line. The towline length is set at three times the towed vessel length with bridle leg lengths equal to the vessels beam. The towline was of 1/32" aircraft cable.

When the towed vessel is released from its offset position, the nature of its oscillations are observed. If the model appears to be unstable, the displacement, frequency, and damping coefficient of the towed vessels reactions are measured. The secondary carriage carries a frame over the full width of the tank with reference marks either side of the centre line of the tank. The towed vessel has a white rod held along its center line. Visual observation refers the centre line of the model to the centre line of the tank to provide indications of directional instability.

The above system can be seen in operation on the video tape recording of the barges runs. A video log is presented as Appendix 2.

Three directional stability runs were carried out at four knots as follows:

1. Light ship with axles mounted but no wheels;
2. 28 tonne condition without axles or wheels; and
3. 28 tonne condition with aft axles and wheels lowered.

DIRECTIONAL STABILITY OBSERVATIONS

1. Light ship

This condition showed surprisingly good directional stability. Without hesitation the barge came into line and remained there throughout the run. It did not cross the centre line of the tank, thus was not considered to oscillate at all.

2. 28 tonne condition - no wheels

After release the barge showed slight hesitation in settling to the centre line. During the remainder of the run there were very slight oscillations about the centre line of the tank. Upon closer examination, it was found that the very light towline used was stretching slightly. Tank personnel commented that directional stability tests were not normally conducted with as large a mass of model with the light line they normally use. In any case, the oscillations were considered to be minor, and the tank personnel believed the barge in this condition to be directionally stable.

3. 28 tonne condition - rear wheels down

On release from the offset position, the barge moved slowly out to the center of the tank and remained there throughout the run.

DIRECTIONAL STABILITY CONCLUSION

The test program called for the directional stability to be tested at both extremes of the displacement range, and at the maximum displacement with the aft wheels down. It was thought that if there was any sign of directional instability, the added resistance of the aft wheels would improve the performance of the barge. If, after these tests, there were any directional stability concerns, further test runs would be made.

In all tests, the barge model exhibited excellent directional stability. There were no indications during these three tests that further tests were necessary.

INCLINING

An inclining experiment was carried out on the model to verify the static stability calculations produced from the Boeing Computer Services SHIPHULL program model.

The model had lead ballast positioned on it for the 16 Tonne condition. It was trimmed to zero trim both fore and aft and athwartships.

For the wheel down condition the foam wheels and axles were placed in the down position. For the wheel up condition the foam wheels were removed and their weight and VCG taken into account when calculating the total model VCG for that condition. The model with the axles and ballast platform mounted was balanced for its VCG. The VCG of the ballast was measured and a total VCG calculated. This figure was input into the Boeing SHIPHULL program.

The model was inclined by shifting the ballast across the ballast platforms. Roll angle was measured using an inclinometer provided by B.C. Research. The shift of ballast was measured against 5 and 10 degree positions. This was done for both the wheel down and wheel up conditions. The results, converted to full scale, are presented in Tables 2 and 3. For comparison the Boeing Shiphull Righting moments are shown. The full Boeing Shiphull input and output are presented in Appendix 3.

TABLE 2

INCLINING TEST WITH WHEELS UP (COMPARED TO BOEING COMPUTER PREDICTION)

	Model (Converted to Full Scale)			Computer Prediction			
Heel Angle (deg.)	Heeling Arm (feet)	Heeling Weight (lbs)	Heeling Moment (ft lbs)	Right Arm (feet)	Displ (lbs)	Righting Moment (ft lbs)	Per Cent Diff
5	0.781	14,875	11,624	0.318	33,375	10,613	8.7
10	1.562	14,875	23,242	0.648	33,375	21,627	6.9

TABLE 3

INCLINING TEST WITH WHEELS DOWN (COMPARED TO BOEING COMPUTER PREDICTION)

	Model (Converted to Full Scale)			Computer Prediction			
Heel Angle (deg.)	Heeling Arm (feet)	Heeling Weight (lbs)	Heeling Moment (ft lbs)	Right Arm (feet)	Displ (lbs)	Righting Moment (ft lbs)	Per Cent Diff
5	2.08	14,875	30,940	0.827	35,190	29,102	5.9
10	4.06	14,875	60,392	1.678	35,190	59,048	2.2

INCLINING CONCLUSIONS

The one-fifth scale tank model results correlated well with the output of the computer model. Thus the computer model can be assumed to be accurate for the barge. The tank model tests differed from the computed predictions from 2 to 9 per cent. This was well within the experimental error of the apparatus used.

SEAKEEPING

Two displacement conditions, 16 and 28 tonne, were chosen to qualitatively evaluate seakeeping characteristics. The 16 tonne condition was evaluated without wheels, with wheels in the down position and wheels up. The 28 tonne condition was evaluated with the wheels in the down position and wheels up. The 28 tonne condition was ballasted to a VCG of 5.28 feet (full scale) and the 16 tonne condition to 5.25 feet (full scale).

The barge was evaluated in head, beam and following seas. The tank wave-maker, fitted at one end of the tank, generated waves down the tank. The model was oriented to the seas as required, and guided by hand-held lines. The model was allowed to move down the tank with the waves.

During head sea tests the model was slowly walked back through the wave spectrum, giving an indication of wetness when making forward progress.

Two sea conditions were used. Spectrum "A" was chosen to represent inshore conditions and Spectrum "B" to represent open water conditions. Waveforms were generated from the B.C. Research Ocean Engineering Centre library of ITTC Irregular Waveforms. The Frequency Spectrum is presented in Graph 5. Spectrum "A" had a significant wavelength (full scale) of 25.6 ft. and significant height (full scale) of 3.5 ft. Spectrum "B" had a significant wavelength (full scale) of 74.1 ft, and significant height (full scale) of 5.0 ft. Spectrum "B" had the highest waveheight that could be generated by the hydraulically-operated computer-controlled wave maker. In fact, some rest periods were required to allow the generator to cool down after over-heating when generating this waveform.

A total of 29 separate tests were evaluated under Seakeeping, listed as run numbers 46 through 74. All were recorded on video tape (Reference the video log in Appendix 2).

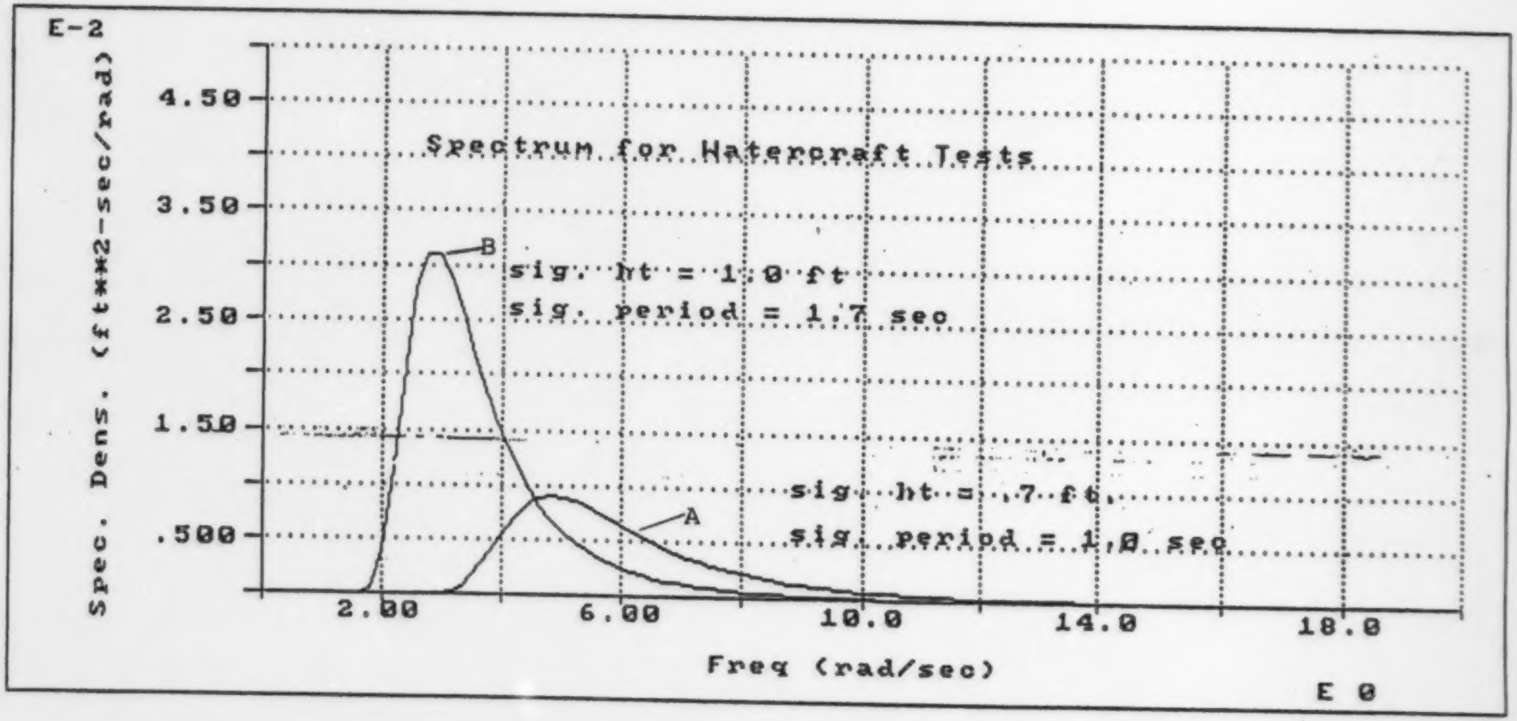
SEAKEEPING CONCLUSIONS

The seakeeping characteristics were qualitatively evaluated. As might be expected, the light ship gave the driest ride with most motion and the 28 tonne condition with wheels down, the reverse.

None of the tests observed, both in Spectrum "A" or "B" waves gave any concern with regards to seakeeping.

Observed pitch, roll and heave motions were considered normal and acceptable. The period, and maximum angle of roll was found to be reduced by immersing the wheels to their maximum depth. As with

GRAPH 5


E-2
Spec. Dens. (ft**2-sec/rad)
4.50
3.50
2.50
1.50
.500
Spectrum for Watercraft Tests
B
sig. ht = 1.0 ft
sig. period = 1.7 sec
A
sig. ht = .7 ft.
sig. period = 1.0 sec
2.00
6.00
10.0
14.0
18.0
Freq (rad/sec)
E 0

roll, the period of pitch was found to change with wheel position.

During tests of the 28 tonne condition, water was seen to slop close to the topside rail edge during beam seas and to the bow rail during head seas. For a barge to operate in the "A" & "B" Spectrum conditions at this displacement may require the freeboard height to be raised. Consideration should be given to decking over a short section of the bow with a raised coaming/water deflector. With regard to the stern, the ramp door will extend well above the topside rail and act as a deflector.

Both Spectrums "A" & "B" had significant wave periods greater than the natural rolling period of the barge in all configurations. Synchronizing of the barge and waves was not observed in any condition. The motion of the barge was such as to not give cause for concern regarding shifting cargoes.

With the luxury of controllable wheel height, the operator of the barge system will have the ability to choose the optimum position of the wheels, depending on the sea conditions.

WATER/ICE TRANSITION

A series of tests were carried out to confirm calculations which predicted that the barge had sufficient freeboard and stability to deal with transitions from water over ice ledges and visa versa. Two displacement conditions, 16 and 28 tonne, were used in these tests. Pneumatic tires nearest to the correct scale were substituted for the foam tires used in the other water tests. Tests were conducted with the tires in two positions:

a) with the tire bottom 10" (full scale) below the barge bottom; and

b) with the tire bottom raised above the barge bottom to reflect the envisioned arrangements the barge would operate under in breaking ice conditions.

The ice ledge model was a plywood and aluminum platform that spanned the width of the tank. The tests were done with the platform 4" (full scale) and 15" (full scale) above the water surface.

The barge was hauled onto the ledge bow on, launched off the ledge both bow and stern on, and also bow on at 45 degrees to represent the barge following the ARKTOS and breaking through on one side.

The barge was hauled onto the ledge by a come-a-long which gave a steady continuous pull. All "launchings" were accomplished by pushing the barge into the water by hand.

A total of 20 tests were carried out and video taped. See runs 75 through 95. (Reference the video log, Appendix 2).

WATER-ICE TRANSITION CONCLUSIONS

The tests confirmed the calculated predictions, which were based on static trim. The stern of the barge did not immerse under any condition when pulled from water to the ledge. When the barge was pushed from the ledge to the water, it generally did not immerse. Slight stern and bow immersion was noticed when the barge was launched rapidly into the water in the 28 tonne condition (stern entry and bow entry at 45 degrees).

Due to the relatively well-damped dynamics of ice failure near water/ice transitions, this minor immersion is not considered to be of great concern. Consideration should be given to decking over a short section of the bow with a raised coaming/water deflector. With regard to the stern, the ramp door will extend well above the topside rail, and thus act as a deflector. These two modifications will remove any concern regarding flooding of the barge during transitions.

OVERLAND TESTS

The barge was fitted with pneumatic tires and towed on different soil conditions. These tests allowed for a qualitative assessment to be made of the towing characteristics of the barge. The wheel positions were varied longitudinally when the initial tests showed that the barge had a tendency to "lope". This characteristic was removed by positioning the aft wheels slightly further aft on the barge.

Resistance tests of the barge were made at the 12.5 tonne condition to determine the general towing resistance of the barge over various conditions. As well, the turning moment of the barge was quantified with respect to the towing loads. See Table 4 for a quantitative summary of the overland towing tests.

Generally, the towing resistance of the barge with wheels was approximately 25 per cent of that when skidded. This was anticipated for a dry, or non-lubricated surface. The turning moments of the barge with wheels was almost equal to that of the barge when skidded. It was important to try to quantify these numbers, as few "trailers" operate on two fixed axles. It was important to determine the mechanics of the barge turning on different surfaces. The turning moment figures will be used as a guide in the design of the scantlings of the barge prototype.

MODEL TEST CONCLUSIONS

The model tests of the passive amphibious barge system have indicated that:

1) The through-water resistance of the barge is within the capabilities of the ARKTOS vehicle. Lowering the wheels into the water significantly increased the towing resistance of the barge. thus to maximize the efficiency of the system, it is important to be able to raise and lower the wheels. The passive amphibious barge system is predicted to operate at 4.25 knots in calm open water;

2) The barge was directionally stable;

3) The computer model static stability predictions were confirmed as accurate;

4) The barge showed no undesirable characteristics in unpowered seakeeping tests;

5) The barge can climb from water to ice and from ice to water without flooding; and

6) The overland turning and towing characteristics of the barge can be anticipated during the design of the barge.

\modrep

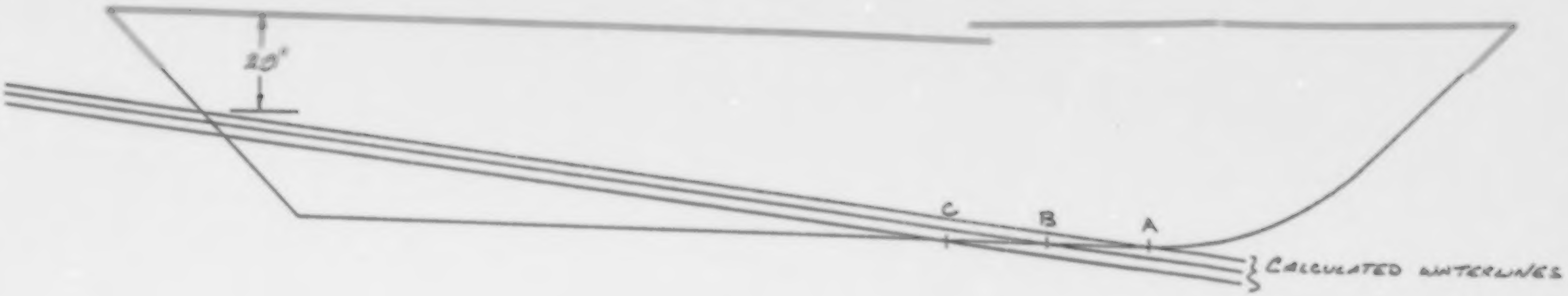
TABLE 4

\BRGGRUND

BARGE MODEL TOWING RESISTANCE
JULY 27 1990

LOAD: 12.5 TONNES
LEVEL GROUND ALL CONDITIONS
MOMENT ARM: (F.S. FT)   6.58 (ASSUMED AT CL OF WHEELS)

CONDITION	TOWING RESIST. (LBS)	TURNING RESIST. (LBS)	TURNING MOMENT (LBS-FT)	F.SCALE RESIST (LBS)	F.SCALE MOMENT (LBS-FT)
1) WITH WHEELS					
BLACKTOP	27	50	329	3375	205729
SMOOTH CONCRETE	27	40	263	3375	164583
GRASS	60	65	428	7500	267448
GRAVEL	24	35	230	3000	144010
2) ON UHMW					
BLACKTOP	140	50	329	17500	205729
SMOOTH CONCRETE	110	40	263	13750	164583
GRASS	110	35	230	13750	144010
GRAVEL	115	40	263	14375	164583



BARGE CONDITION: 12 TONNE CARGO

ICE LEDGE POSITIONS: "A", "B" & "C"

BASIC CALCULATION: BALANCE OF MOMENTS
(AS PER LAUNCHING CALCULATION)

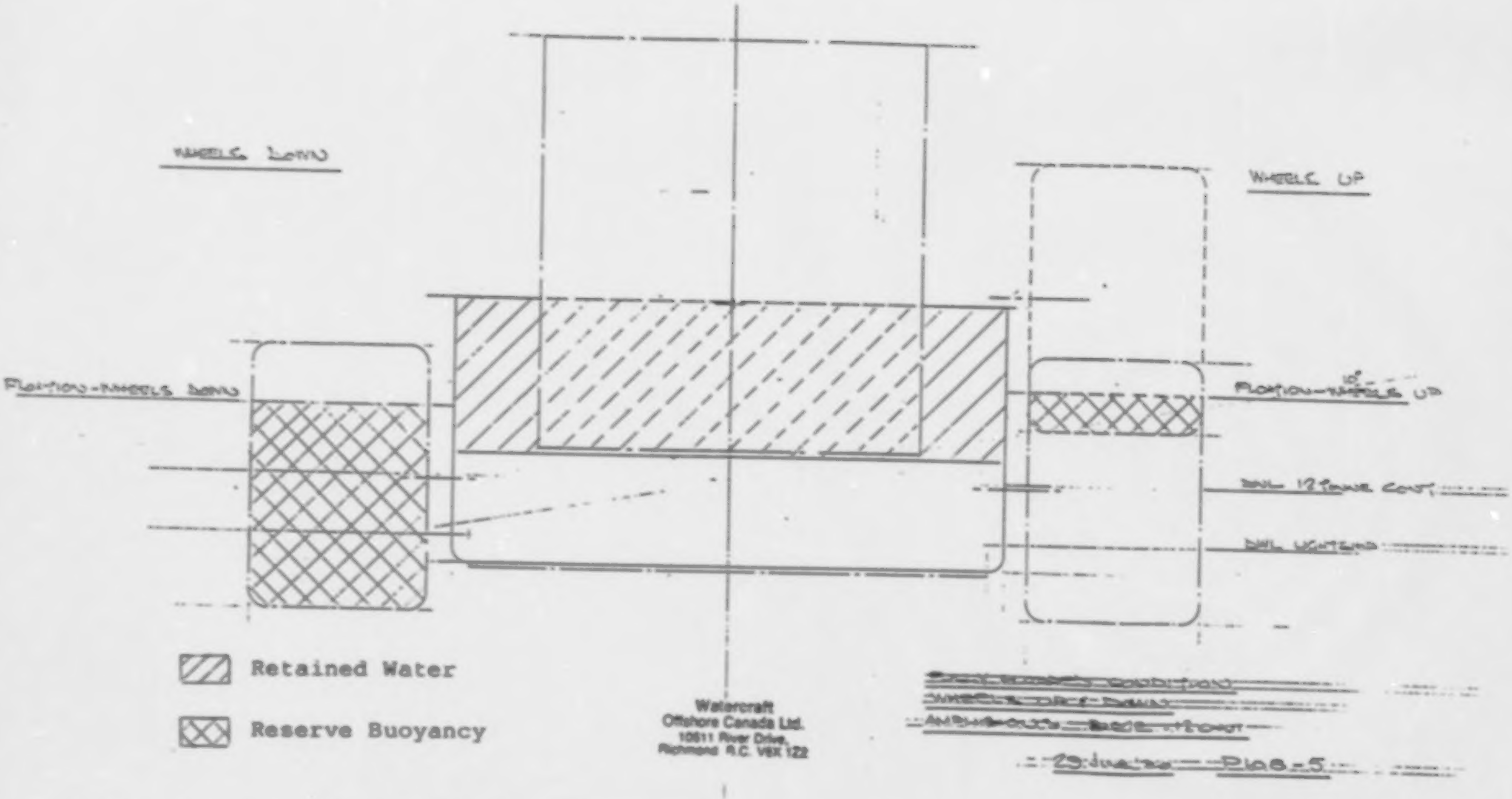
ASSUMPTIONS: IGNORED EFFECTS OF TOWLINE FORCE & WHEEL BUOYANCY.

WORST CASE: PIVOT ABOUT POINT 'A' LEAVES MINIMUM FREEBOARD OF 20" FULL SCALE AT STERN

MODEL TEST RESULT: WITH WHEELS & TOWLINE FORCE: FREEBOARD OF 30" FULL SCALE AT STERN

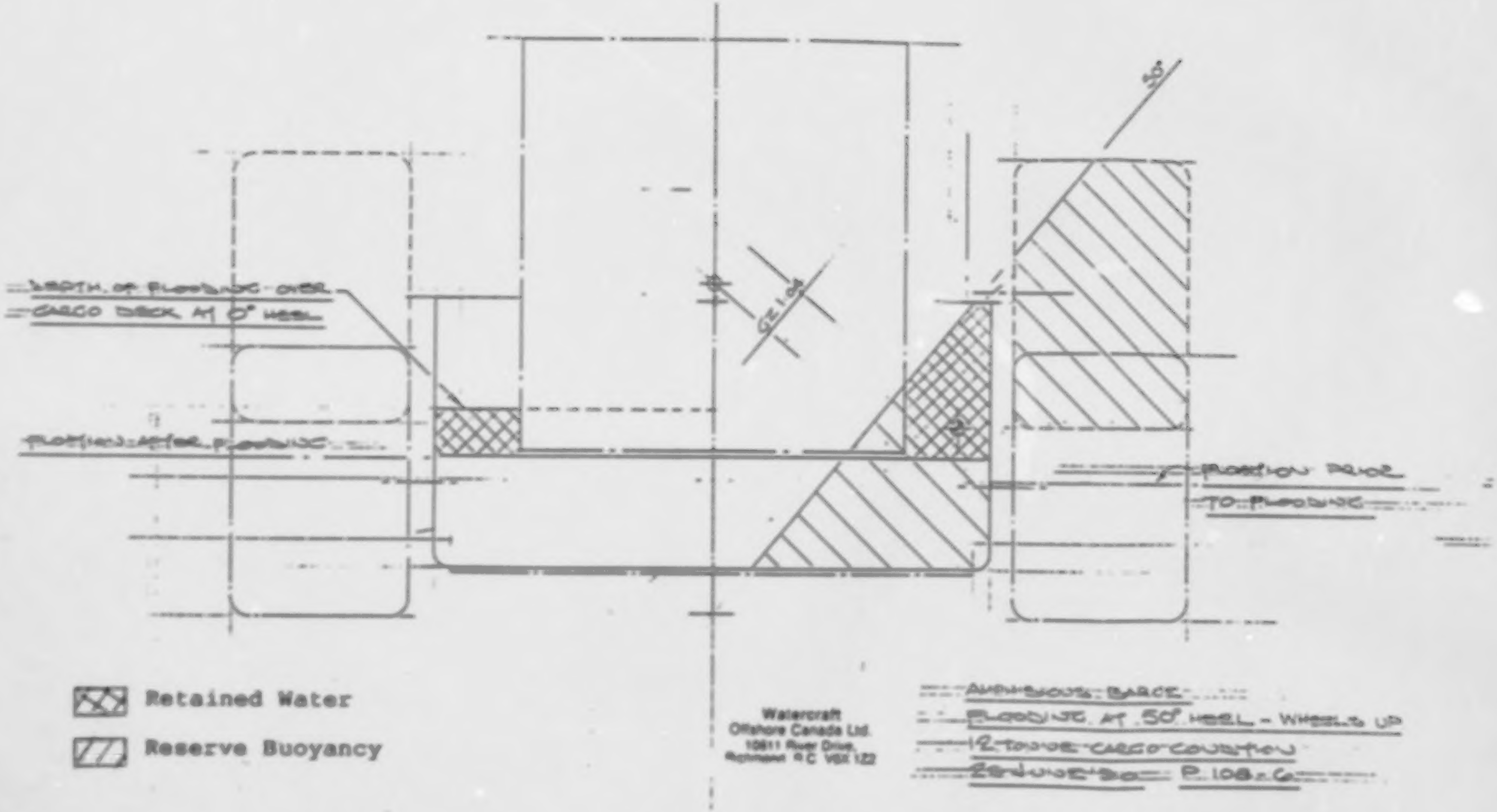
BARGE CLIMB-OUT CALCULATION RESULTS

Watercraft Offshore Canada Ltd.
10611 River Drive
Richmond, British Columbia
Canada V6X 1Z2


WHEELS DOWN
WHEELS UP
FLOTATION-WHEELS DOWN
10°
FLOTATION-WHEELS UP
DWL 12 TONNE CONT.
Retained Water
Reserve Buoyancy
Watercraft
Offshore Canada Ltd.
10611 River Drive,
Richmond B.C. V6X 1Z2
29 Jun '90
P108-5

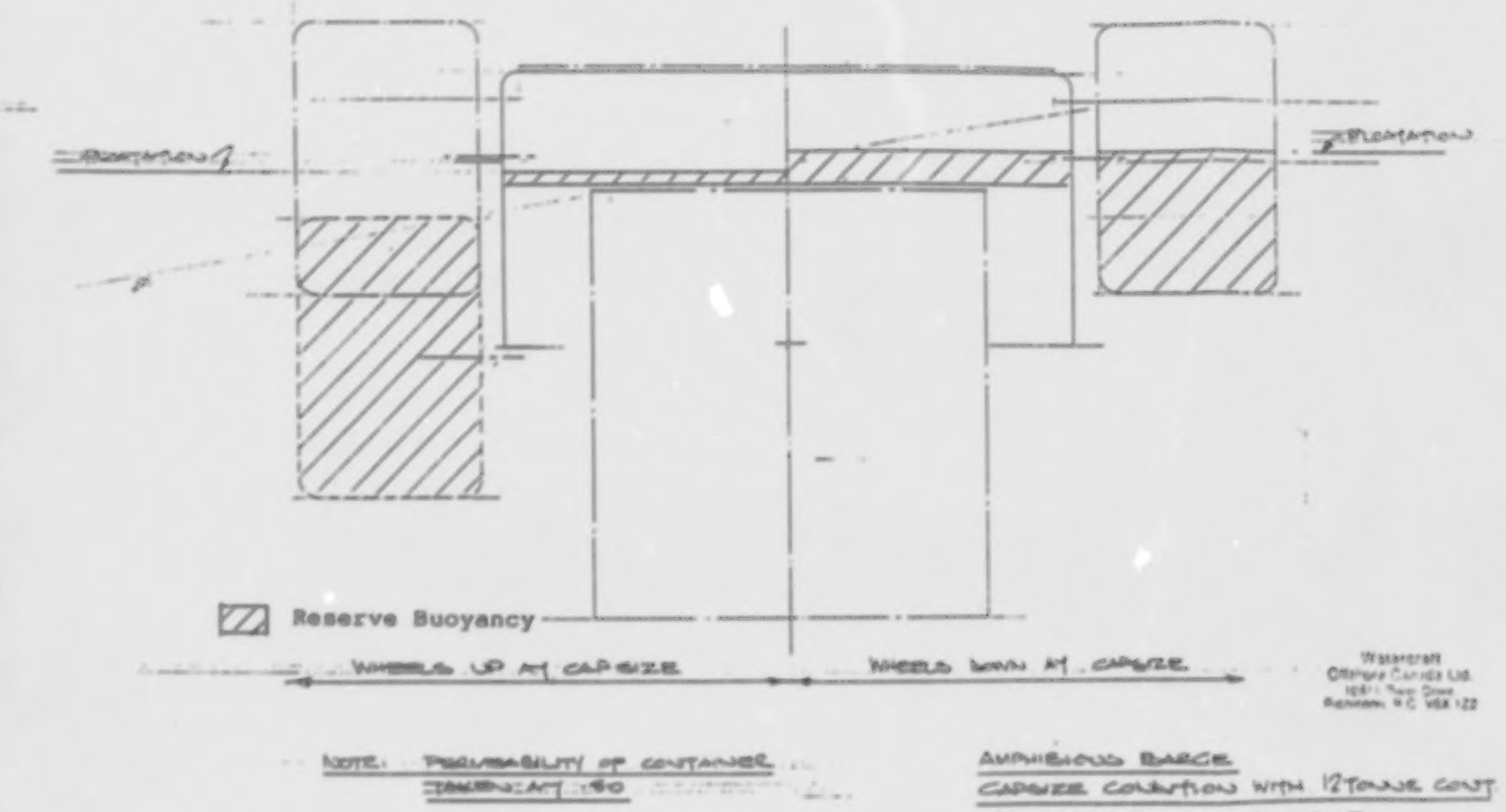
P108-5 ARKTOS PASSIVE AMPHIBIOUS BARGE SYSTEM: Effects of water retained on the deck

X



50°
DEPTH OF FLOODING OVER
CARGO DECK AT 0° HEEL
GZ 1.05
FLOTATION AFTER FLOODING
FLOTATION PRIOR
TO FLOODING
Retained Water
Reserve Buoyancy
Watercraft
Offshore Canada Ltd.
10811 River Drive,
Richmond B C V6X 1Z2
AMPHIBIOUS BARGE
FLOODING AT 50° HEEL - WHEELS UP
12 TONNE CARGO CONDITION
28 JUNE '90
P.108-6

P108-6 ARKTOS PASSIVE AMPHIBIOUS BARGE SYSTEM: Effects of heel to deck edge immersion



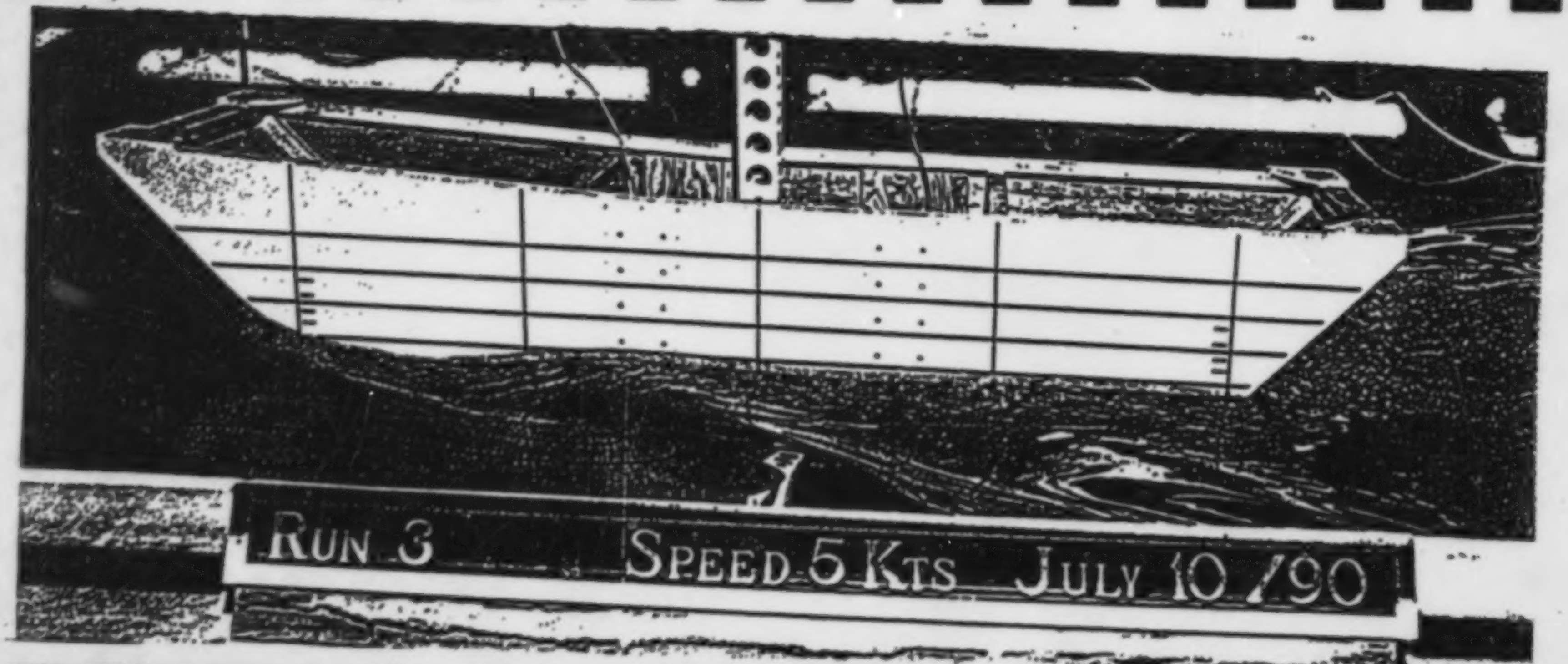
FLOTATION
▨ Reserve Buoyancy
WHEELS UP AT CAPSIZE
WHEELS DOWN AT CAPSIZE
Watercraft
Offshore Canada Ltd.
NOTE: PERMEABILITY OF CONTAINER
TAKEN AT .90
AMPHIBIOUS BARGE
CAPSIZE CONDITION WITH 12 TONNE CONT
29 JUNE '80.
P108-7

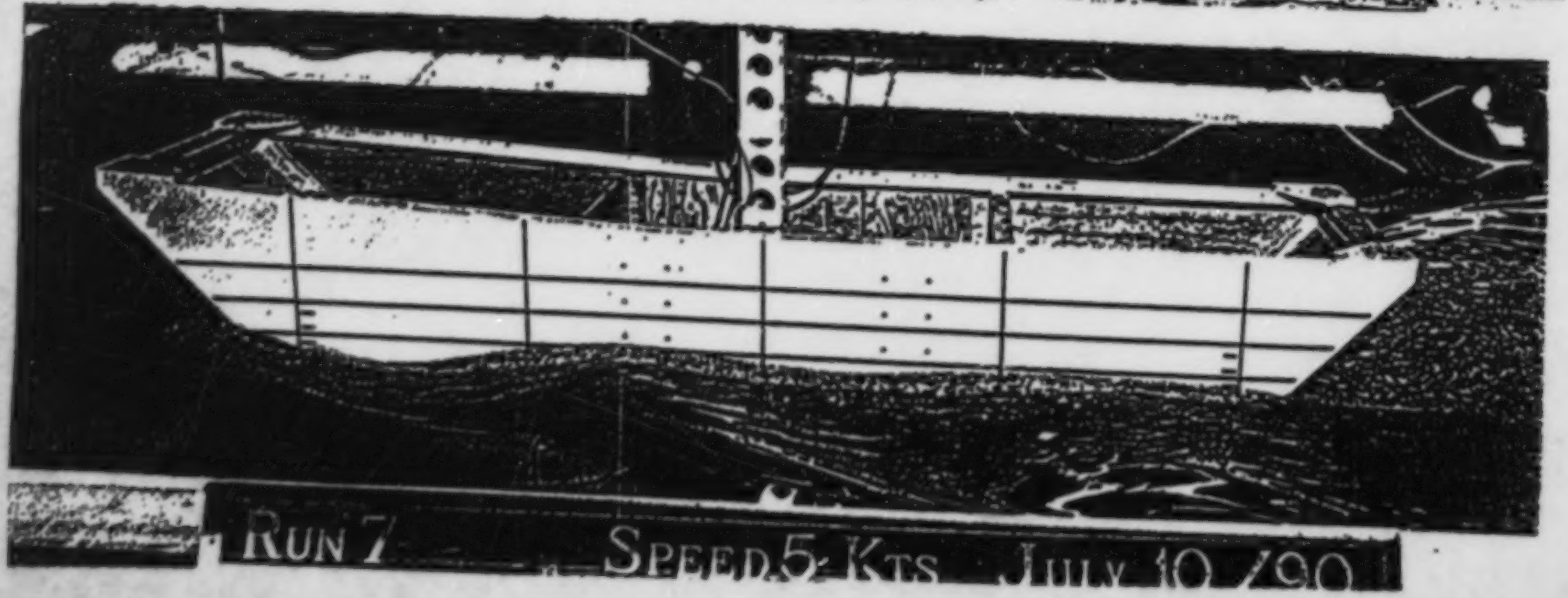
P108-7 ARKTOS PASSIVE AMPHIBIOUS BARGE SYSTEM: Effects of total capsize

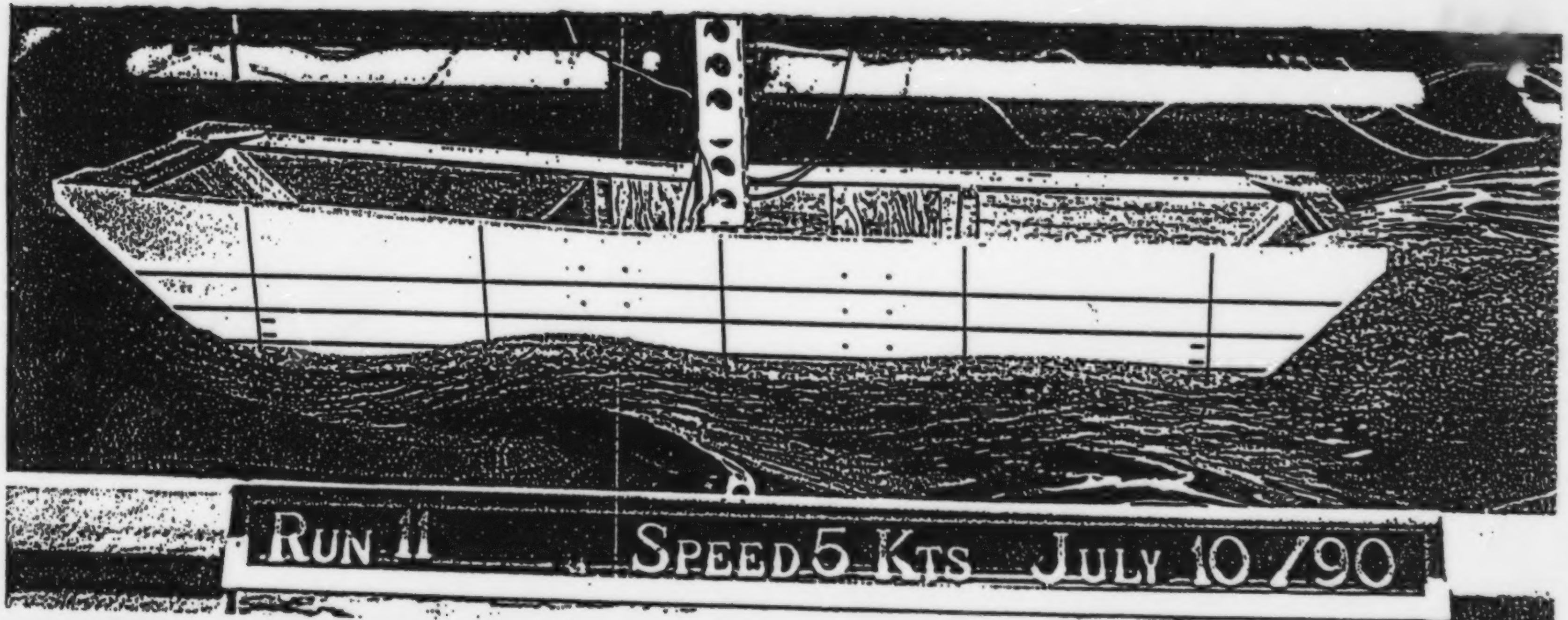
ATTACHMENT I

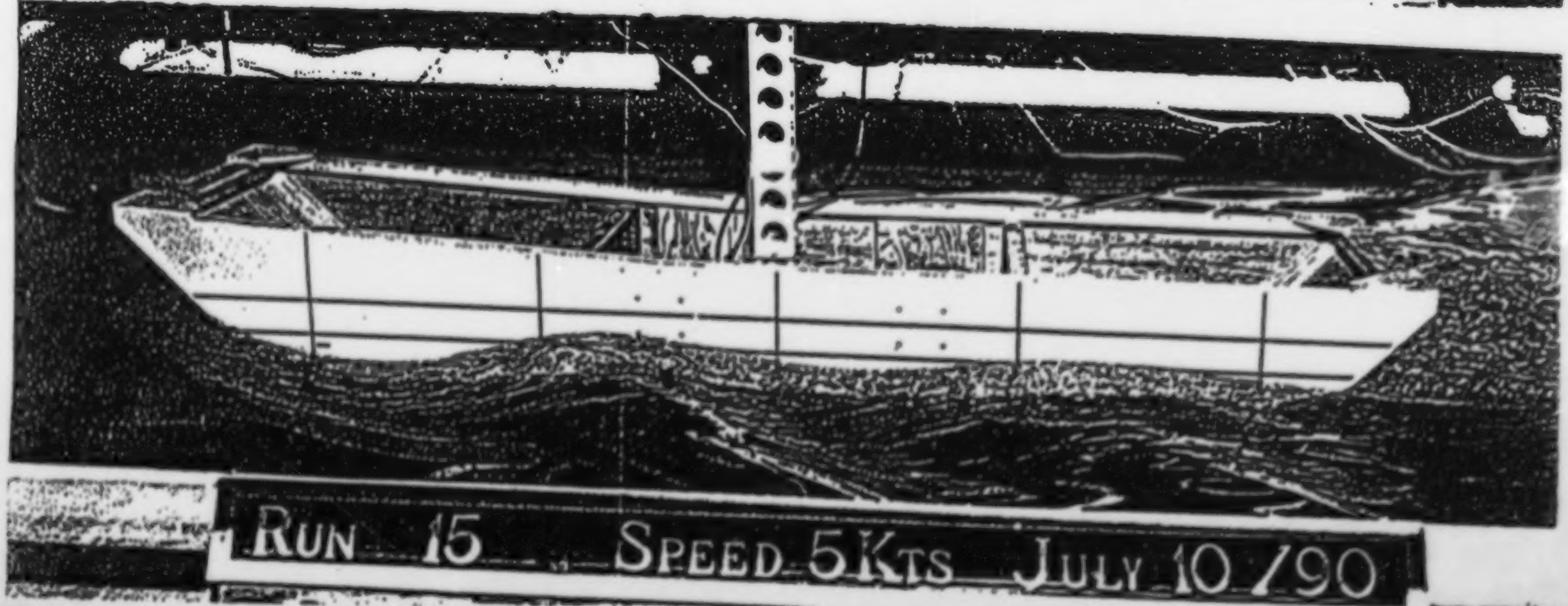
MODEL RESISTANCE TEST PHOTOGRAPHS

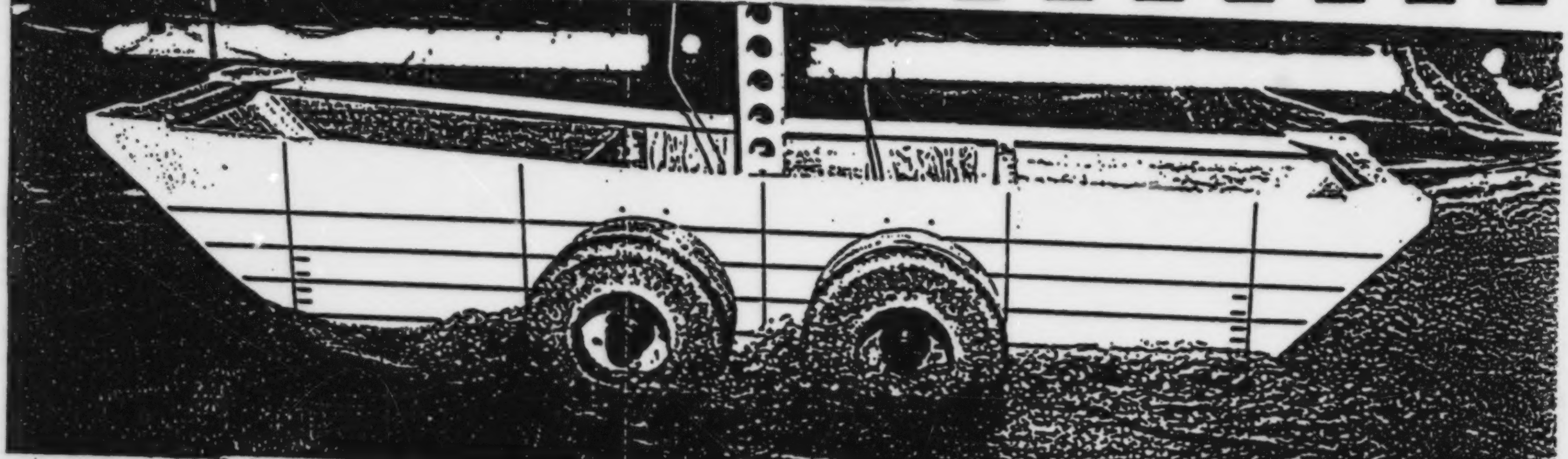
(Refer to Table 1 for index to measured data)


RUN 3
SPEED 5 KTS
JULY 10/90

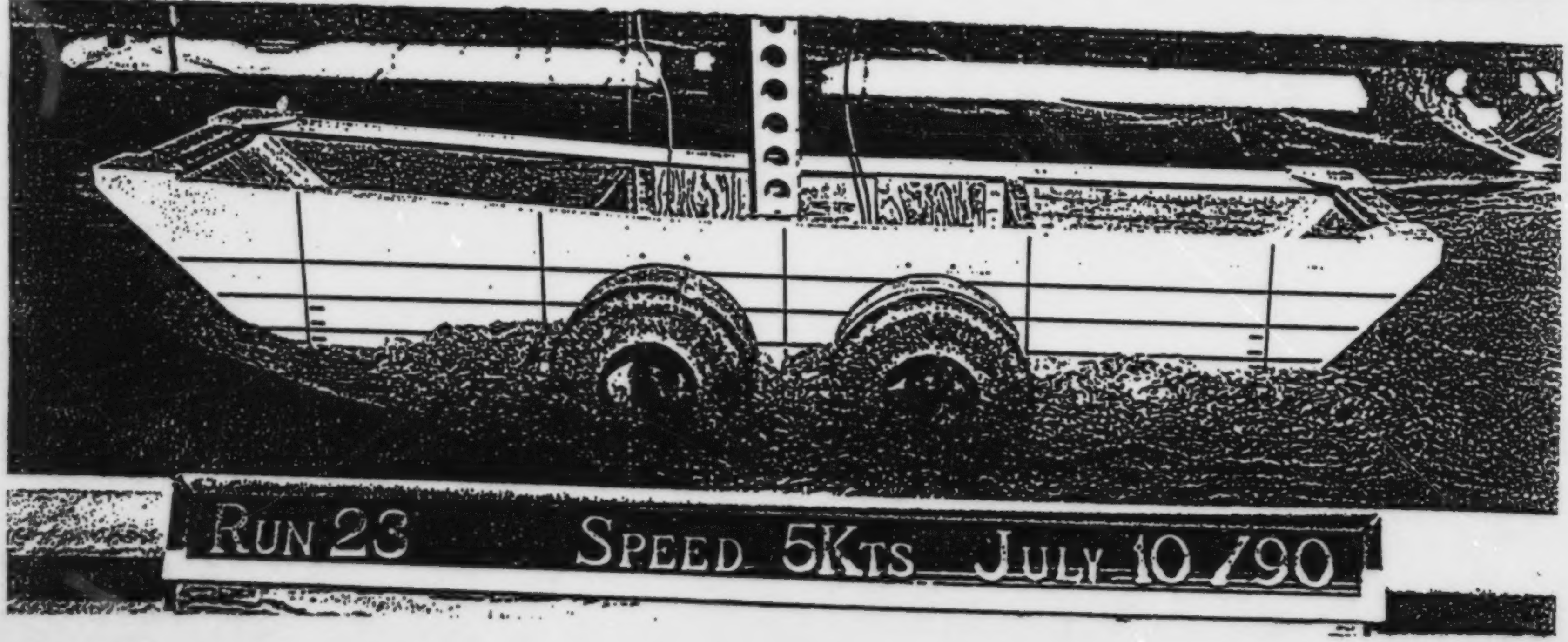

RUN 7
SPEED 5 KTS
JULY 10/90


RUN 11 SPEED 5 KTS JULY 10/90

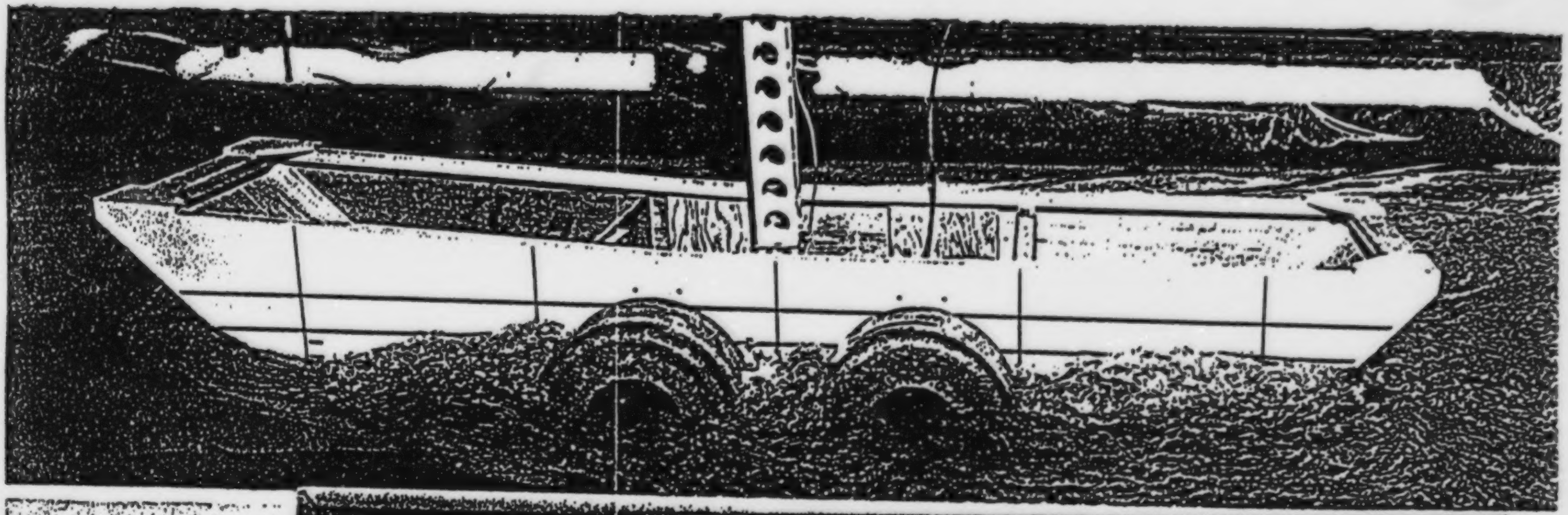

RUN 15 SPEED 5 KTS JULY 10/90



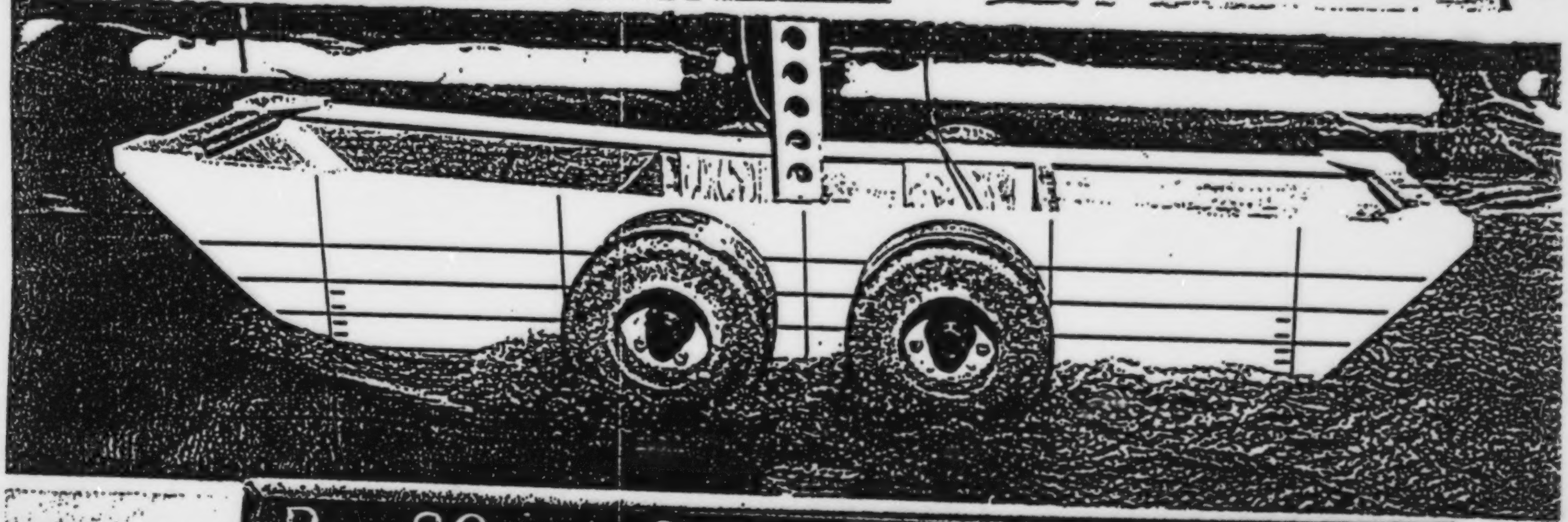
Run 19 Speed 5Kts July 10/90



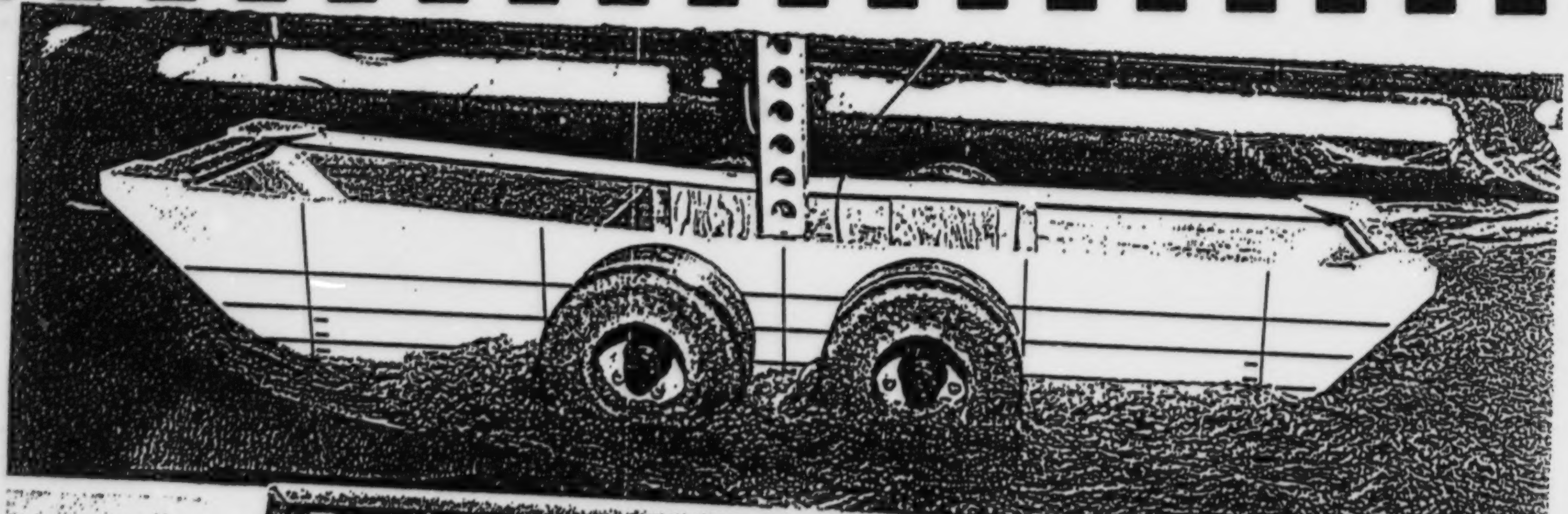
Run 23 Speed 5Kts July 10/90



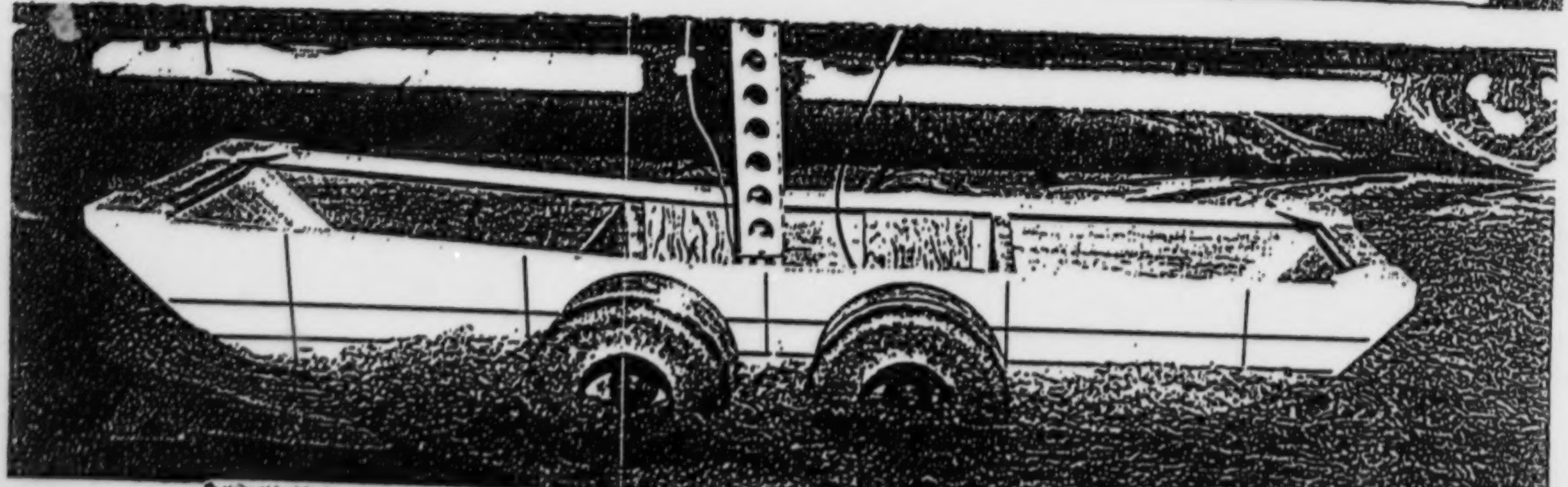
RUN 27 SPEED 5KTS JULY 10/90



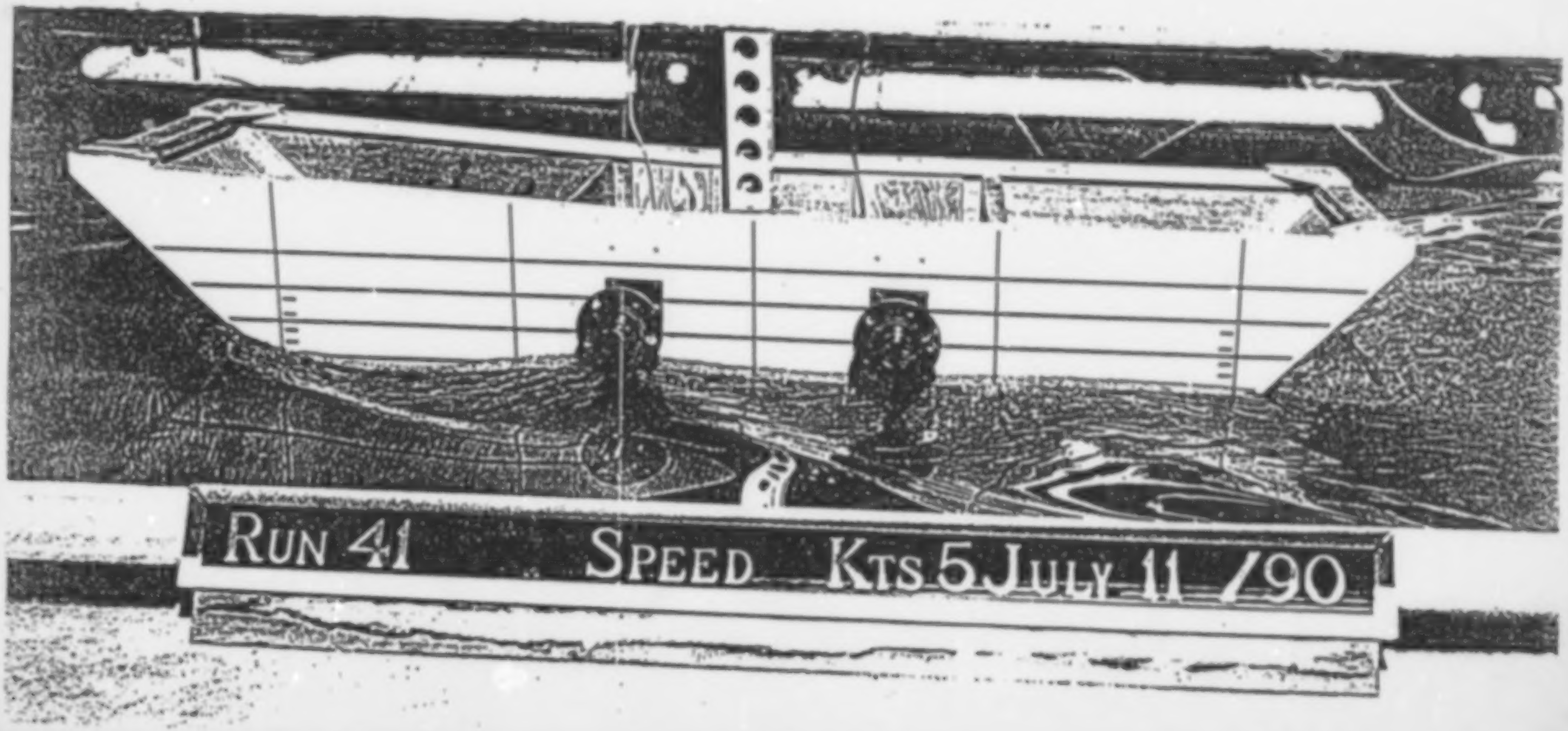
RUN 30 SPEED 5KTS JULY 10/90



RUN 33 SPEED 5 KTS JULY 10/90



RUN 37 SPEED 5 KTS JULY 11/90


RUN 41
SPEED KTS 5
JULY 11 /90

ATTACHMENT 2

VIDEO LOG

(N.B. Video already with TDC)

VIDEO RECORD - BARGE TEST PROGRAM @ OEC JULY 11-13, 1990

RUN		COUNTER
43	DIRECTIONAL STABILITY - NO WHEELS, WITH AXLE, LIGHTSHIP - SPEED = 4 KNOTS	120-190
44	DIRECTIONAL STABILITY - NO WHEELS OR AXLE, 28 TONNES - SPEED = 4 KNOTS	235-282
45	DIRECTIONAL STABILITY - AFT WHEELS ON, 28 TONNES - SPEED = 4 KNOTS	472-524
46	SEAKEEPING - HEADSEAS - WHEELS DOWN - 16 TONNES - WAVE SPECTRUM B	870-1155
47	SEAKEEPING - BEAM SEAS - WHEELS DOWN - 16 TONNES - WAVE SPECTRUM B	1162-1283
48	SEAKEEPING - BEAM SEAS - WHEELS DOWN - 16 TONNES - WAVE SPECTRUM A	1292-1399
49	SEAKEEPING - FOLLOWING SEAS - WHEELS DOWN - 16 TONNES - WAVE SPECTRUM A	1431-1530
50	SEAKEEPING - FOLLOWING SEAS - WHEELS DOWN - 16 TONNES - WAVE SPECTRUM B	1533-1627

51	SEAKEEPING - HEAD SEAS - WHEELS MIDWAY - 16 TONNES - WAVE SPECTRUM B	1639-1725
52	SEAKEEPING - BEAM SEAS - WHEELS MIDWAY - 16 TONNES - WAVE SPECTRUM B	1729-1812
53	SEAKEEPING - FOLLOWING SEAS - WHEELS HIGH - 16 TONNES - WAVE SPECTRUM B	1820-1890
54	SEAKEEPING - FOLLOWING SEAS - WHEELS MIDWAY - 16 TONNES - WAVE SPECTRUM A	1905-1980
55	SEAKEEPING - BEAM SEAS - WHEELS MIDWAY - 16 TONNES - WAVE SPECTRUM A	1990-2058
56	SEAKEEPING - HEAD SEAS - WHEELS MIDWAY - 16 TONNES - WAVE SPECTRUM A (WALKED BACK)	2065-2165
57	SEAKEEPING - HEAD SEAS - NO WHEELS - 16 TONNES - WAVE SPECTRUM A	2174-2236
58	SEAKEEPING - BEAM SEAS - NO WHEELS - 16 TONNES - WAVE SPECTRUM A	2244-2320

59	SEAKEEPING - FOLLOWING SEAS - NO WHEELS - 16 TONNES - WAVE SPECTRUM A	2321-2708
60	SEAKEEPING - FOLLOWING SEAS - NO WHEELS - 16 TONNES - WAVE SPECTRUM B	2421-2495
61	SEAKEEPING - BEAM SEAS - NO WHEELS - 16 TONNES - WAVE SPECTRUM B	2510-2584
62	SEAKEEPING - HEAD SEAS - NO WHEELS - 16 TONNES - WAVE SPECTRUM B (WALKED BACK)	2586-2682
63	SEAKEEPING - HEAD SEAS - WHEELS DOWN - 28 TONNES - WAVE SPECTRUM B	2705-2770
64	SEAKEEPING - BEAM SEAS - WHEELS DOWN - 28 TONNES - WAVE SPECTRUM B	2780-2850
65	SEAKEEPING - FOLLOWING SEAS - WHEELS DOWN - 28 TONNES - WAVE SPECTRUM B	2860-2939
66	SEAKEEPING - FOLLOWING SEAS - WHEELS DOWN - 28 TONNES - WAVE SPECTRUM A	2955-3020

67	SEAKEEPING - BEAM SEAS - WHEELS DOWN - 28 TONNES - WAVE SPECTRUM A	3038-3080
68	SEAKEEPING - HEAD SEAS - WHEELS DOWN - 28 TONNES - WAVE SPECTRUM A (WALKED BACK)	3084-3275
69	SEAKEEPING - HEAD SEAS - WHEELS MIDWAY - 28 TONNES - WAVE SPECTRUM A	3280-3330
70	SEAKEEPING - BEAM SEAS - WHEELS MIDWAY - 28 TONNES - WAVE SPECTRUM A	3371-3416
71	SEAKEEPING - FOLLOWING SEAS - WHEELS MIDWAY - 28 TONNES - WAVE SPECTRUM A	3428-3476
72	SEAKEEPING - FOLLOWING SEAS - WHEELS MIDWAY - 28 TONNES - WAVE SPECTRUM B	3493-3538
73	SEAKEEPING - BEAM SEAS - WHEELS MIDWAY - 28 TONNES - WAVE SPECTRUM B	3543-3595
74	SEAKEEPING - HEAD SEAS - WHEELS MIDWAY - 28 TONNES - WAVE SPECTRUM B (WALKED BACK)	3604-3678

75	WATER/ICE TRANSITION - BOW CLIMB OUT - WHEELS DOWN - 28 TONNES	3875-3905
76	WATER/ICE TRANSITION - SLOW LAUNCH BACKWARDS (ARM CATCHES ON STEP) - 28 TONNES	3919-3926
77	WATER/ICE TRANSITION - BOW CLIMB OUT (SAME CONDITION AS 75) - 28 TONNES	3935-3946
78	WATER/ICE TRANSITION - FAST BACKWARDS LAUNCH - 28 TONNES	3950-3960
79	WATER/ICE TRANSITION - STERN CLIMB OUT - 28 TONNES	3968-3978
80	WATER/ICE TRANSITION - FORWARD FAST LAUNCH - 28 TONNES	3998
81	WATER/ICE TRANSITION - 45o BOW LAUNCH - 28 TONNES	3997
82	WATER/ICE TRANSITION - 45o BOW LAUNCH - WHEELS ABOVE BARGE BOTTOM (BARGE SKIDDING) - 29 TONNES	4030-4053
83	WATER/ICE TRANSITION - FORWARD CLIMB OUT - WHEELS ABOVE BARGE BOTTOM - 29 TONNES	4043-4058
84	WATER/ICE TRANSITION - STERN LAUNCH (SLOW ARM CATCHES) - WHEELS ABOVE BARGE BOTTOM - 29 TONNES	4064-4073

85	WATER/ICE TRANSITION - BOW CLIMBOUT - WHEELS ABOVE BARGE BOTTOM - 16 TONNES	4079-4091
86	WATER/ICE TRANSITION - STERN LAUNCH (SLOW) - WHEELS ABOVE BARGE BOTTOM - 16 TONNES	4104-4111
87	WATER/ICE TRANSITION - 45o BOW LAUNCH - WHEELS ABOVE BARGE BOTTOM - 16 TONNES	4121-4125
88	WATER/ICE TRANSITION - STRAIGHT BOW LAUNCH - WHEELS ABOVE BARGE BOTTOM - 16 TONNES	4131-4134
89	WATER/ICE TRANSITION - 45o BOW LAUNCH - WHEELS DOWN - 16 TONNES	4135-4140
90	WATER/ICE TRANSITION - BOW LAUNCH - WHEELS DOWN - 16 TONNES	4142-4149
91	WATER/ICE TRANSITION - BOW CLIMB OUT - WHEELS DOWN - 16 TONNES	4160-4168
92	WATER/ICE TRANSITION - STERN LAUNCH - WHEELS DOWN - 16 TONNES	4168-4173
93	WATER/ICE TRANSITION - * STEP RAISED 15" (FULL SCALE) ABOVE WATER - CLIMB OUT WINCHED - WHEELS DOWN - 16 TONNES	4177-4188

94	WATER/ICE TRANSITION - * STEP RAISED 15" - STERN LAUNCH - WHEELS DOWN - 16 TONNES	4204-4207

END OF TAPE

ATTACHMENT 3

BOEING COMPUTER "SHIPHUL"
COMPUTER MODEL
INPUT/OUTPUT

TWO CONDITIONS:

(a) WHEELS DOWN
(b) WHEELS UP

```
COMPUTER MODEL DEFINITION INPUT

10005 BARGE WITH WHEELS DWN (INCL)   JULY12
 006000000000000000000000001003000000000000
 3.091     0.005     0.005     30.917    1.960        02
 -0.997 5.750 5.250  +77777
 -0.997 5.755 5.500  +88888
 -0.498 5.750 3.375  +77777
 -0.498 5.755 5.500  +88888
  0.000 5.750 1.910  +77777
  0.000 5.755 5.500  +88888
  0.823 5.750 0.458  +77777
  0.823 5.755 5.500  +88888
  1.647 5.750 0.000  +77777
  1.647 5.755 5.500  +88888
  2.940 5.750 0.000  +77777
  2.940 5.755 5.500  +88888
  4.234 5.750 0.000  +77777
  4.234 5.755 5.500  +88888
  5.527 5.750 0.000  +77777
  5.527 5.755 5.500  +88888
  6.821 5.750 0.000  +77777
  6.821 5.755 5.500  +88888
  8.115 5.750 0.000  +77777
  8.115 5.755 5.500  +88888
  9.409 5.750 0.000  +77777
  9.409 5.755 5.500  +88888
 10.217 5.750 2.500  +77777
 10.217 5.755 5.500  +88888
 11.026 5.750 5.000  +77777
 11.026 5.755 5.500  +99999
21.33     8.08      1.75      3.83      3.66      5.25      0.00
11.78     8.08      1.75      3.83      3.66      5.25      0.00
      0.00      15.71999999999999999999         35.9
00100     15.71
00100     00.00                                                  1
          4.32
010      5.0    10.0    12.0    15.0    20.0    25.0    30.0    40.0    50.0    60.0
9999
```

```
1
 ***************************************************************
 BOEING SHIP HULL CHARACTERISTICS PROGRAM (SHIPHUL) - VERSION 1.5
 GENERAL HYDROSTATICS SUBPROGRAM (HYSTAT)
 DATED SEPTEMBER 19, 1985
 PROGRAM DOCUMENTATION-
    BOEING SHIP HULL CHARACTERISTICS PROGRAM USER MANUAL
    D324-11002-1E
    M.D.DEVINE
    OCTOBER, 1980
 ***************************************************************
1SHIP-      BARGE WITH WHEELS DWN (INCL)       SERIAL NUMBER-     5   DATE-JULY12

OTABLE OF OFFSETS - INPUT DATA
OTHE FOLLOWING PAGES CONTAIN THE OFFSETS AS SUBMITTED.
ODEFINITIONS AND UNITS
OZ - HEIGHT ABOVE BASELINE, FT
 Y - HALF BREADTH, FT
1SHIP-      BARGE WITH WHEELS DWN (INCL)       SERIAL NUMBER-     5   DATE-JULY12
OTABLE OF OFFSETS - INPUT DATA
OSTATION    -.997  LOCATED   -3.082 FT FROM FP
       Z          Y
     5.250      5.750
     5.500      5.755
OSTATION    -.498  LOCATED   -1.539 FT FROM FP
       Z          Y
     3.375      5.750
     5.500      5.755
OSTATION    0.000  LOCATED    0.000 FT FROM FP
       Z          Y
     1.910      5.750
     5.500      5.755
OSTATION     .823  LOCATED    2.544 FT FROM FP
       Z          Y
      .458      5.750
     5.500      5.755
OSTATION    1.647  LOCATED    5.091 FT FROM FP
       Z          Y
     0.000      5.750
     5.500      5.755
OSTATION    2.940  LOCATED    9.088 FT FROM FP
       Z          Y
     0.000      5.750
     5.500      5.755
OSTATION    4.234  LOCATED   13.087 FT FROM FP
       Z          Y
     0.000      5.750
     5.500      5.755
OSTATION    5.527  LOCATED   17.084 FT FROM FP
       Z          Y
     0.000      5.750
     5.500      5.755
```

```
OSTATION    6.821  LOCATED   21.084 FT FROM FP
        Z          Y
      0.000      5.750
      5.500      5.755
OSTATION    8.115  LOCATED   25.083 FT FROM FP
        Z          Y
      0.000      5.750
      5.500      5.755
OSTATION    9.409  LOCATED   29.083 FT FROM FP
        Z          Y
      0.000      5.750
      5.500      5.755
OSTATION   10.217  LOCATED   31.581 FT FROM FP
        Z          Y
      2.500      5.750
      5.500      5.755
1SHIP-     BARGE WITH WHEELS DWN (INCL)       SERIAL NUMBER-    5   DATE-JULY12
OTABLE OF OFFSETS - INPUT DATA
OSTATION   11.026  LOCATED   34.081 FT FROM FP
        Z          Y
      5.000      5.750
      5.500      5.755
1                       APPENDAGE VOLUME DATA-PAGE 1 OF 2

 VOL     CENTROID COORD,FT     RECTANGULAR LENGTHS,FT    RT ANGLE   VOLUME
 NO.       X        Y        Z        X       Y       Z        DEG       FT3
  1     21.33    8.08    1.75      3.83    3.66    5.25        0.00      73.59
  2     11.78    8.08    1.75      3.83    3.66    5.25        0.00      73.59
1                       APPENDAGE VOLUME DATA-PAGE 2 OF 2

 VOL   X COORD,FT         FORWARD AND AFT FACE CORNER COORDINATES,FT
 NO.   FWD     AFT       Y-----Z        Y-----Z        Y-----Z        Y-----Z
  1   23.25  19.42      6.25   4.38    9.91   4.38    9.91  -.88    6.25  -.88
  2   13.70   9.87      6.25   4.38    9.91   4.38    9.91  -.88    6.25  -.88


TOTAL APPENDAGE VOLUME(STARBOARD HALF), FT3 =      147.19
```

```
1SHIP-     BARGE WITH WHEELS DWN (INCL)        SERIAL NUMBER-    5   DATE-JULY12

ODESIGN DISPLACEMENT              15.710 LTON FW
 DESIGN LCG                        0.000 FT FROM AMIDSHIPS (+ FWD)
 DESIGN DRAFT                      1.381 FT
 DESIGN TRIM                       -.408 FT (+ BY STERN)
OLENGTH OVERALL                   37.163 FT
 LENGTH BETWEEN PERPENDICULARS    30.917 FT
 LENGTH ON DESIGN WATERLINE       29.814 FT
OSTATION OF MAX AREA (AT DWL)      4.902 FT FROM FP
 BEAM AT STATION OF MAX AREA      11.503 FT
 SECTION AREA COEFFICIENT          .9999
 PRISMATIC COEFFICIENT             .8109
 BLOCK COEFFICIENT                 .8108
1SHIP-     BARGE WITH WHEELS DWN (INCL)        SERIAL NUMBER-    5   DATE-JULY12

   1 INPUT DISPLS     15.710
   1 INPUT LCGS        0.000
   1 INPUT POLES       4.320
  10 INPUT HEELS       5.000     10.000     12.000     15.000     20.000
                      25.000     30.000     40.000     50.000     60.000

                 DEFINITIONS
ODISPL  DISPLACEMENT, LTON FW
 LCG    LCG FROM AMIDSHIPS (+ FWD), FT
 HEEL   INPUT HEEL ANGLE, DEGREES
 TCB    TRANSVERSE CENTER OF BUOYANCY FROM CL, FT
 VCB    VERTICAL CENTER OF BUOYANCY ABOVE BL, FT
 RA     RIGHTING ARM, FT
 DRAFT  DRAFT AMIDSHIPS, FT
 TRIM   TOTAL TRIM (+ BY STERN), FT
1SHIP-     BARGE WITH WHEELS DWN (INCL)        SERIAL NUMBER-    5   DATE-JULY12

0                      INTACT CURVES OF STATICAL STABILITY

    DISPL      LCG    POLE HT   HEEL      RA      TCB      VCB       DRAFT        TRIM

    15.710    0.000     4.32    5.000    .827    1.151     .660      1.373       -.368
                               10.000   1.678    2.322     .815      1.366       -.372
                               12.000   2.029    2.800     .908      1.361       -.371
                               15.000   2,500    3.461    1.064      1.336       -.382
                               20.000   2.834    4.127    1.268      1.193       -.430
                               25.000   2.815    4.465    1.406       .986       -.466
                               30.000   2.656    4.684    1.520       .729       -.490
                               40.000   2.158    4.988    1.732       .006       -.517
                               50.000   1.548    5.219    1.962     -1.147       -.574
                               60.000    .816    5.363    2.166     -2.989       -.801

 CPU TIME =    .221 SECONDS.
1
C>
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COMPUTER MODEL DEFINITION INPUT

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10006 BARGE WITH WHEELS UP  (INCL)   JULY12
 006000000000000000000000001003000000000000
 3.091      0.005      0.005      30.917    1.960        00
 -0.997 5.750 5.250  +77777
 -0.997 5.755 5.500  +88888
 -0.498 5.750 3.375  +77777
 -0.498 5.755 5.500  +88888
  0.000 5.750 1.910  +77777
  0.000 5.755 5.500  +88888
  0.823 5.750 0.458  +77777
  0.823 5.755 5.500  +88888
  1.647 5.750 0.000  +77777
  1.647 5.755 5.500  +88888
  2.940 5.750 0.000  +77777
  2.940 5.755 5.500  +88888
  4.234 5.750 0.000  +77777
  4.234 5.755 5.500  +88888
  5.527 5.750 0.000  +77777
  5.527 5.755 5.500  +88888
  6.821 5.750 0.000  +77777
  6.821 5.755 5.500  +88888
  8.115 5.750 0.000  +77777
  8.115 5.755 5.500  +88888
  9.409 5.750 0.000  +77777
  9.409 5.755 5.500  +88888
 10.217 5.750 2.500  +77777
 10.217 5.755 5.500  +88888
 11.026 5.750 5.000  +77777
 11.026 5.755 5.500  +99999
      0.00     14.90999999999999999999      35.9
00100     14.90
00100     00.00                                                       1
           4.42
010      5.0   10.0   12.0   15.0   20.0   25.0   30.0   40.0   50.0   60.0
9999
```

```
1
 ************************************************************
 BOEING SHIP HULL CHARACTERISTICS PROGRAM (SHIPHUL) - VERSION 1.5
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    D324-11002-1E
    M.D.DEVINE
    OCTOBER, 1980
 ************************************************************
1SHIP-     BARGE WITH WHEELS UP  (INCL)       SERIAL NUMBER-    6   DATE-JULY12

0TABLE OF OFFSETS - INPUT DATA
0THE FOLLOWING PAGES CONTAIN THE OFFSETS AS SUBMITTED.
0DEFINITIONS AND UNITS
0Z - HEIGHT ABOVE BASELINE, FT
 Y - HALF BREADTH, FT
1SHIP-     BARGE WITH WHEELS UP  (INCL)       SERIAL NUMBER-    6   DATE-JULY12
0TABLE OF OFFSETS - INPUT DATA
0STATION    -.997  LOCATED   -3.082 FT FROM FP
        Z          Y
      5.250     5.750
      5.500     5.755
0STATION    -.498  LOCATED   -1.539 FT FROM FP
        Z          Y
      3.375     5.750
      5.500     5.755
0STATION    0.000  LOCATED    0.000 FT FROM FP
        Z          Y
      1.910     5.750
      5.500     5.755
0STATION     .823  LOCATED    2.544 FT FROM FP
        Z          Y
       .458     5.750
      5.500     5.755
0STATION    1.647  LOCATED    5.091 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
0STATION    2.940  LOCATED    9.088 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
0STATION    4.234  LOCATED   13.087 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
0STATION    5.527  LOCATED   17.084 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
```

```
0STATION    6.021  LOCATED   21.084 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
0STATION    8.115  LOCATED   25.083 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
0STATION    9.409  LOCATED   29.083 FT FROM FP
        Z          Y
      0.000     5.750
      5.500     5.755
0STATION   10.217  LOCATED   31.581 FT FROM FP
        Z          Y
      2.500     5.750
      5.500     5.755
1SHIP-     BARGE WITH WHEELS UP  (INCL)       SERIAL NUMBER-    6   DATE-JULY12
0TABLE OF OFFSETS - INPUT DATA
0STATION   11.026  LOCATED   34.081 FT FROM FP
        Z          Y
      5.000     5.750
      5.500     5.755
```

```
1SHIP-     BARGE WITH WHEELS UP  (INCL)        SERIAL NUMBER-    6   DATE-JULY12

 0DESIGN DISPLACEMENT              14.900 LTON FW
  DESIGN LCG                        0.000 FT FROM AMIDSHIPS (+ FWD)
  DESIGN DRAFT                      1.660 FT
  DESIGN TRIM                       -.259 FT (+ BY STERN)
 0LENGTH OVERALL                   37.163 FT
  LENGTH BETWEEN PERPENDICULARS    30.917 FT
  LENGTH ON DESIGN WATERLINE       30.452 FT
 0STATION OF MAX AREA (AT DWL)      4.934 FT FROM FP
  BEAM AT STATION OF MAX AREA      11.503 FT
  SECTION AREA COEFFICIENT          .9999
  PRISMATIC COEFFICIENT             .8603
  BLOCK COEFFICIENT                 .8602
1SHIP-     BARGE WITH WHEELS UP  (INCL)        SERIAL NUMBER-    6   DATE-JULY12

    1 INPUT DISPLS      14.900
    1 INPUT LCGS         0.000
    1 INPUT POLES        4.420
   10 INPUT HEELS        5.000      10.000      12.000      15.000      20.000
                        25.000      30.000      40.000      50.000      60.000

                 DEFINITIONS
 0DISPL  DISPLACEMENT, LTON FW
  LCG    LCG FROM AMIDSHIPS (+ FWD), FT
  HEEL   INPUT HEEL ANGLE, DEGREES
  TCB    TRANSVERSE CENTER OF BUOYANCY FROM CL, FT
  VCB    VERTICAL CENTER OF BUOYANCY ABOVE BL, FT
  RA     RIGHTING ARM, FT
  DRAFT  DRAFT AMIDSHIPS, FT
  TRIM   TOTAL TRIM (+ BY STERN), FT
1SHIP-     BARGE WITH WHEELS UP  (INCL)        SERIAL NUMBER-    6   DATE-JULY12

0                         INTACT CURVES OF STATICAL STABILITY

     DISPL      LCG    POLE HT    HEEL      RA      TCB       VCB       DRAFT        TRIM

     14.900    0.000     4.42     5.000    .318     .628      .885      1.653        -.232
                                 10.000    .648    1.267      .969      1.644        -.223
                                 12.000    .787    1.527     1.020      1.638        -.225
                                 15.000   1.002    1.923     1.115      1.627        -.221
                                 20.000   1.274    2.494     1.293      1.571        -.214
                                 25.000   1.375    2.898     1.460      1.439        -.209
                                 30.000   1.377    3.207     1.620      1.238        -.203
                                 40.000   1.218    3.669     1.943       .611        -.195
                                 50.000    .870    3.962     2.231      -.358        -.241
                                 60.000    .347    4.114     2.445     -1.843        -.318

 CPU TIME =     .165 SECONDS.
1
```

APPENDIX III

Detailed Design

1. **Canarctic Shipping Company Limited**
Extract from Design, Development and Testing
of the Arktos Passive Amphibious Barge System
Task #4
Section 4.0
Section 5.0

2. Watercraft Offshore Canada Ltd.

Detailed Design of Barge and Components

References

4.0 Detailed Design

Watercraft's design submission was reviewed by Mariport and their commentary on the fulfilment of Task #2 parameters is attached at Appendix 4.

Whilst conceding that most major parameters had been translated into the design, Mariport had reservations which can be grouped as follows:

a) Degree of engineering detail and materials of construction

b) Prediction of overland performance

c) Viability in field operations

d) Achievement of payload objectives.

These reservations and Watercraft's response (see Appendix 5) are summarized in the following paragraphs.

4.1 Engineering Detail/Materials of Construction

The constructional drawings generated by Watercraft do not cover all details of openings, fastenings, etc., as they are directed towards structural fitness for purpose. To this extent the ABS endorsement of PABS Construction Plan 108-8-R this has been achieved. In any further construction phase, ABS supervision would cover the details pointed out by Mariport. The present set of constructional drawings would probably not be suitable for a third party manufacturer/constructor.

Aluminum was chosen for its light weight, ease of manipulation in fabrication, ease of executing changes and to some extent its ease of repair. Aluminum does not have a favourable track record in rugged environments and this is recognized by:

a) the heavy UHMW polyethylene sheathing of the bottom and ramped ends;

b) internal sub-division has been increased from four compartments to seven to provide a greater degree of survivability from damage from any quarter;

c) the scantlings chosen are compatible with construction practice and any scantling increases would be subjective as no Classification guidance exists.

4.2 Overland Performance

The model tests extrapolated to full size provided barge rolling and sliding resistance over a number of prepared surfaces quite unrelated to "real" surfaces likely to be encountered in the field. Additionally the effect of graded surfaces was not addressed. No correlation was made to the tractive effort of the towing vehicle. This information has now been provided and predicts that for a fully loaded barge (22.5 tonnes) in the rolling mode and the towing vehicle in first gear, the limiting grade angles are 41 and 33 degrees for snow and mud respectively. In second gear the corresponding angles are 19 and 11.5 degrees.

4.3 Field Operations

Mariport are sceptical that some of the features, notably ramp and gantry, will perform adequately in the Arctic environment. This is a subjective judgement with which Watercraft subjectively disagree.

This part of the Project is not seeking absolute solutions but covering off the basics to ensure confidence in any prototype that might be constructed. This has been carried out and it is the nature of the following Phases that field experience will dictate changes in design detail and methods of operation.

4.4 Payload Capability

(i) The estimated weight of the barge as calculated from the constructional drawings is 8.85 tonnes: this exceeds the expected weight of 6.5 tonnes by 2.35 tonnes. This has implications for load carrying in respect of deck line, loaded water line and the stern ramp sealing arrangements.

The primary Project pay load requirement is 12.5 tonnes which with a barge weight of 8.85 tonnes gives an all up displacement of 21.35 tonnes. In this condition and ignoring the effects of the wheels, the water line (or draft) is estimated at 26.20 inches (as opposed to 24 inches expected) some 1.80 inches below the line of the deck edge. The ramp seal at this condition is half submerged.

In the higher payload condition, viz. 20 tonne container and cargo and 8.85 tonne barge = 28.85 tonne all up displacement, the waterline is now estimated to be some 5.85 inches above the line of the deck edge: the ramp seal is now fully submerged. By lowering the wheels the waterline or draft will decrease by some 5.75 inches, clearly a better state of affairs with respect to the ramp seal but not acceptable from towing resistance purposes.

These waterlines are shown in Diagram 1.

(ii) Structurally the barge is capable of supporting a fully loaded 20ft container considered as a 4 point load or alternatively 20 tonnes distributed around the deck. This is one of the criteria applied by ABS.

Watercraft's revised design submission is attached at Appendix 6 and Mariport's acceptance of it is attached at Appendix 7.

5.0 Other Considerations

During Tasks #2 and 3 a number of issues were identified for further attention. These were:

5.1 Static Stability

It was noted from preliminary stability data presented at Task #2 that the wheelless barge apparently had a rapidly declining angle of vanishing stability and GZ at displacements in excess of 19 tonnes. This data has been checked and an error in the 17 tonne calculation has been discovered. In this case the combined VCG has been taken as 3.25ft - this should have been 5.76ft. This reduces that static stability curve to much nearer to the 19 tonne case and drastically reduces the rate of decline.

In the model tests, the VCG of the barge was determined physically and this when combined with the increased weight of the barge structure gives static stability characteristics across the displacement spectrum as shown in Diagram 2.

It should also be noted that the cargo VCG is assumed at half container height, a situation not likely to be encountered in practice where VCG's would be lower so improving static stability characteristics over those shown.

5.2 Damaged Condition

The initial design called for a barge internal sub-division into four compartments and required "buoyancy" assistance from the wheels to remain afloat in all but one case of a breached compartment. This was deemed to be unacceptable. The internal compartments were increased to seven thereby delaying the point at which wheel "buoyancy" assistance is required to remain afloat. This has been a subjective approach as no published guidance exists for this type of craft. It should be added that in a production barge situation, the preferred material of construction would be composites, a much tougher and physical damage resistant material than aluminum.

5.4 Cost of Construction

In parallel with the design development, it has been estimated that the construction of a prototype unit would cost $90,000 in direct material charges plus 143 man days over an elapsed time of 10 weeks.

Passive Amphibious Barge System (PABS)

Detailed Design
of Barge and Components

October 25, 1990

Watercraft Offshore Canada Ltd.

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Executive Summary

Schedule of Drawings

1.0 General Arrangement

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1.2 Construction

1.2.1 Welding

1.3 Hull

1.4 Ramp/Door

1.5 Lifting Arrangements

1.6 Securing of Cargo

1.7 Securing of Barge

1.8 Forward and Aft towing Points

1.9 Bottom Sheathing

1.10 Cargo Deck

1.11 Load Plate

1.12 Damaged Hull Condition

1.13 Wheel Arrangement

1.14 Hydraulic System

1.15 Construction Sequence

2.0 Gantry Arrangement

2.1 Gantry - Method of Operation

2.1.1 Assembly

2.1.2 Operational Sequence

3.0 Cost Estimate

4.0 Weight Estimate

References

References

1. Construction Rules:

   - ABS Rules for Building and Classing Steel Barges for Offshore Service, 1973.

2. Construction Plan Approval:

   - ABS letter dated September 4, 1990: File Ref. T-8-Z.
   - Watercraft Drawing No. 108-8-R dated August 20, 1990 endorsed by ABS September 4, 1990

3. Aluminium Specification

   - BS 5083
   - BS 6061

4. Steel Specification

   - ASTM A57Z Grade 50

5. UHMW Polythene Specification

   - Redco UHMW Fact Sheet

6. Engine Specification

   - Kubota D1402-B

7. Weight Estimate (Attached)

8. Material Cost Estimate (Attached)

EXECUTIVE SUMMARY

The detailed design stage of the Passive Amphibious Barge System (PABS) program followed the conceptual design criteria set out during the previous stages of the project. No unforeseen design problems were encountered during this phase. Detail work was carried out, the results are presented in drawings which must be considered an integral part of this report.

The PABS concept components which have been detailed include:

1) Barge
2) Ramp
3) Tow Point
4) Wheel Lifting Structure
5) Wheel Lifting Hydraulic System
6) Cargo Handling Gantry

The work has proceeded to the point that an accurate cost estimate for the construction of the PABS has been completed. Direct materials for the barge have been estimated to cost $90,000, and 143 person-days over an elapsed time of 10 weeks are required for construction. The completed barge should have a weight of approximately 19,500 pounds. The maximum design cargo load of the barge is 12.5 tonnes.

The PABS has now reached the stage to allow the next logical development steps: construction and testing.

SCHEDULE OF DRAWINGS

The following Watercraft Offshore Canada Ltd. drawings make up an integral part of this report:

Title	Drawing Number
Construction Plan	108-8-R
Ramp Assembly	108-9-R
Wheel Assembly	108-10-R
Fwd. Towing Assembly	108-14-D
Hydraulic Schematic	108-22-B
Gantry Arrangement	108-23-D
Hull Compartments	108-24-B
Hydraulic Power Pack Arrangement	108-25-B

1.0 GENERAL ARRANGEMENT

The Passive Amphibious Barge System (PABS) was designed to transport general bulk or containerized cargo over water, ice or land.

The barge structure was based around a tank bottom, the top of which is designed to be above the barge Datum Waterline when fully loaded. The sides of the barge are extended upward to provide additional freeboard, to retain the cargo, and to keep it dry from seawater. The sides incorporate four wheel housings, which provide for vertical movement of large pneumatic tired wheels. The ends of the barge are raked and freeboard is increased at the forward end.

The wheels, a major feature of the barge, are mounted on carriages which slide vertically within wheel housings. The height of the wheels is varied through the use of hydraulic cylinders. This system allows the wheels to be positioned to best advantage over the range of surfaces the barge is expected to work.

The tank bottom of the barge is subdivided into seven compartments. This arrangement isolates any holing of the bottom, improving the damaged condition of the barge over that of a non divided tank. The arrangements are described in Section 1.12, Damaged Hull Condition.

The tanks for the hydraulic system, oil and diesel are fitted into the forward compartment. The prime mover and associated equipment will be on a skid frame mounted on the deck over the forward compartment with an insulated engine box over.

At the aft end of the barge a hinged ramp closes off the access for loading/unloading cargo. The arrangements are described in Section 1.4, Ramp / Door.

The barge has lifting eyes to enable the barge, complete with a full load of cargo to be crane lifted. There are also eye plates for securing all types of cargoes including a standard 20 foot shipping container.

The barge is fitted with forward and aft towing eyes. There are also mooring/towing bitts at both the bow and stern. For further details of all the above see Drawing Number 108-8-R, Construction Plan.

In addition to the wheels, the barge bottom is sheathed with UHMW to allow skidding of the barge over ice and other terrains as necessary.

1.1 SCANTLINGS

As recorded in "Interim Report - Task #2", the barge will be built to American Bureau of Shipping (ABS) rules for Steel Barges, modified for aluminum as contained in ABS rules Aluminum Vessels 1975. (See References 1, 3 and 4.))

A Construction Plan, Drawing Number 108-8-R has been prepared and submitted to ABS which has approved the scantlings and arrangements specified (See Reference 2).

1.2 CONSTRUCTION

As noted under Scantlings, the barge will be built to ABS rules and under the Bureau's Supervision. It will then be eligible to be classed as A1 Barge, River, Bay and Sound Service.

1.2.1 WELDING

The Bureau will require a welding specification to be submitted which will cover type, size and sequence.

1.3 HULL

The hull is essentially a tank bottom with single skin topsides above the double bottom. Framing is a combination system of longitudinal frames including two full depth girders supported by regularly spaced transverse frames. The tank bottom is formed by the single bottom shell plating and the cargo deck plating. The tank bottom is divided into seven separate compartments by two watertight bulkheads and the two fore and aft girders. Each compartment has an inspection hatch, as required by ABS.

1.4 RAMP/DOOR

The arrangement of the Ramp is shown on Drawing No. 108-9-R. The purpose of the ramp is to allow the moving of cargo in and out of the barge by wheeled loader or skids. Though the cargo deck is above Datum waterline in the loaded condition it is thought necessary for the ramp/door to have watertight integrity to deal with stern sinkage when launching and cargo damage when in a seaway.

The ramp is essentially an aluminum sandwich panel. This design was chosen for its inherently high stiffness. The panel has inner and outer 1/4 inch plates with 1/4 inch internal stiffeners in egg box form.

The ramp is to be hinged to the barge on its lower edge. The hinge pins are to work in elongated holes to allow the ramp to be pulled into neoprene seals along the ramp edges. Tensioning toggles will pull the lower part of ramp into the seals. The upper part of the ramp is to be lowered, or raised and pulled into the seals by a wire pennant passing over a sheave onto a hand winch.

Water could be be drained off the cargo deck when the ramp is raised by releasing the tensioning toggles on the lower part of the ramp. This will allow the hinge pins to slide in their elongated holes.

Loose bridging plates are to be provided to bridge the gap between ramp edge and cargo deck. The plates are to be retained by locating lugs.

1.5 LIFTING ARRANGEMENTS

The barge has been designed with fixed lifting eyes to accept the shackles of the wire strops.

The design lift load is the barge weight plus the cargo. A safety factor of six was used in the design of the lifting components.

The lifting strops will require spreader bars or a spreader frame to give a clear lead to a single lift crane.

The lifting eyes are incorporated into the structure using a plate system that will adequately spread the load.

1.6 SECURING OF CARGO

The barge has been designed with fixed eye plates to accept retainer chains for the container. Loose cargo will be retained by lashings to ring eye plates bolted to each side frame.

1.7 SECURING OF BARGE

The barge is to have suitable lashing points for securing the barge to a ship's deck to allow transport of the barge at sea. The forward and aft towing points, the lifting eye plates and the forward and aft mooring bitts can be used for this purpose. These points are already sufficiently strengthened to allow use for their primary purpose. Extra securing points, especially those outboard of the barge are undesirable as they are very vulnerable to ice damage during barge operation.

1.8 FORWARD AND AFT TOWING POINTS

As the forward towing point will be required to accept pull from a range of directions, the eye attachment has been designed as a universal joint on the centreline. The tow point has suitable anchor plates taken through the bottom plating and welded to fore and aft girders. See Drawing No. 108-14-D.

The aft towing point is a fixed eye plate located on the centreline. The shear path for the anchor plate is distributed between the bottom plating and the deck plating before reaching the fore and aft longitudinals.

1.9 BOTTOM SHEATHING

The bottom is to be sheathed with Ultra High Molecular Weight Polyethylene (UHMW). This is the same material as used in the track slider system of the ARKTOS vehicle. It has extremely low sliding resistance, good wear characteristics and excellent cold-temperature characteristics. (See Reference 5 for Technical Specification of this material)

The sheathing is attached to the bottom plating by tee bar guides set at approximately 15 inch centres. This will facilitate the periodic renewal of the sheathing and possible repair of locally damaged sheathing. For details see Drawing. No. 108-8-R.

1.10 CARGO DECK

During the development of the PABS, it was thought necessary to sheath the cargo deck. Problems in attaching any sheathing due to space restriction in the tank bottom and the necessity to make an absolute watertight connection dictated further discussion.

The outcome was an aluminum only deck using Tread Plate to give a degree of non-slip for personnel during loading/unloading operations. The deck will have appropriate strengthening in the area of the container corners.

1.11 LOAD PLATE

The barge will be fitted with a fixed load plate, specifying the cargo to be loaded is not to exceed 12.5 tonnes. This plate will also carry a statement that the barge is not approved for carrying personnel.

1.12 DAMAGED HULL CONDITION

To contain a possible damaged hull condition with the minimum weight penalty the tank bottom is divided into seven compartments formed by the scantling structure. The arrangement and identification is shown on Drg. No. 18-24 B, "Hull Compartments".

Table (1) shows the effect of holing any one compartment or combination of compartments on the reserve buoyancy. The total buoyancy of all four tires is taken into account but no buoyancy has been assumed from the 12.5 tonne cargo.

The UHMW sheathing at 62 lbs per cu.ft. is assumed as neutral and has been deducted from the total weight to be supported.

TABLE (1)

DAMAGED COMP.	REMAINING BUOYANCY	REQ. BUOYANCY FROM TIRES	POS./NEG. CONDITION
A	684 cu.ft.	14 cu.ft.	POS.
B	709	NIL	"
C	708	"	"
D	709	"	"
E	759	"	"
F	752	"	"
G	759	"	"
AB	550	148	"
BE	624	74	"
ABE	466	232	"
BEF	533	165	"
ABC	415	283	"
EFG	583	115	"
BCD	440	258	"
BEFG	449	249	"
BEDG	406	292	EQ.
ABEF	375	323	NEG.
ABCD	281	408	"
BCDE	355	343	"
BCEF	398	300	"

NOTES

Total weight to be supported is 21.35 tonnes, requiring 735 cu. ft. of displacement (salt water). Total non-floodable volume of barge, allowing for material thickness, is 37 cu. ft., thus total buoyancy required to be supported is 698 cu. ft.

Barge is considered to be fully loaded, with 12.5 tonnes cargo, which has a permeability of 1.00, thus it does not displace any volume. The ramp seal is assumed to be damaged. Total volume of the seven compartments is 842 cu. ft. Total volume available from the wheels is 298 cu. ft. Compartment permeability is assumed to be 1.00.

In this condition, any two compartments can be damaged and the barge remains afloat.

If the compartments were to be filled with a material which resulted in a permeability of 25 per cent, the barge would remain afloat with all seven compartments flooded.

1.13 WHEEL ARRANGEMENT

The arrangement of the wheel structure is shown in Drawing 108-10-R. During travel on land, the barge is supported by 4 floatation tires, each measuring 66 inches in diameter and 44 inches in width. This large section is chosen to minimize ground pressure. The tread pattern of these tires is very smooth and will cause minimal damage to the terrain. These wheels are supported by a structure which allows the wheels to be hydraulically raised and lowered to suit the mode of travel. On firm ground, the wheels will be lowered in respect to the barge, and provide 12 inches of ground clearance. In conditions where the ground is very soft, the wheels will be raised to allow the barge to be slid on its UHMW sheathed bottom. In the water, the wheels are raised above the waterline in order to reduce water resistance. For travel in mixed ice and water conditions, they are raised to their highest position of 12 inches above waterline to clear the unbroken ice left beside Arktos. In total, each wheel has 54 inches of vertical travel.

The wheel carriage is constructed mostly of box sections of A572/50 grade steel having a yield strength of 50,000 psi. These sections are guided within aluminum channels mounted vertically in the side walls of the barge. UHMW is used as a bearing material between the carriage and channel. A double acting hydraulic cylinder with a 4 inch bore, 2 inch rod, and 54 inch stroke operates at 2000 psi, to actuate the carriages. For ease of servicing, the cylinder mounting is arranged such that the cylinder can be removed without disturbing the wheel carriage.

The wheel arrangements are designed to lift and lower the barge in the 12.5 tonnes cargo load condition with a safety factor of four.

1.14 HYDRAULIC SYSTEM

The raising and lowering of the wheels is to be done hydraulically. This method was choosen as it gives good control, requires little custom machining or fabrication, and is suitable to prototype systems as it is relatively easy to modify or to use as a power source for as yet unspecified functions.

The circuit is depicted in schematic form in Drawing Number 108-22-B. Generally, a double gear pumpset drives the wheel cylinders through an open circuit. Each section of the pumpset controls two cylinders. The forward cylinders are actuated as a pair, and the aft cylinders are actuated as a pair. This will allow the barge to be pitched when on land or in water. This is seen as an advantage over pairing the cylinders on each side of the barge.

The cylinders are locked in place with pilot-operated check valves. These are required to prevent the cylinders from creeping under load due to leakage through the spool valve.

The spool valves are to be radio controlled, to allow actuation from the towing vehicle. Manual over rides are to be provided as well, to allow actuation from the barge. As the distance between the barge and the towing vehicle can be varied, the valves can not be actuated through fixed wires. The valves are non-modulating. Radio control of such a valve is done with well known technology, thus the cost is not prohibitive.

The flow to and from each cylinder is regulated from the pump through flow divider-combiner valves. Although these valves will not perfectly match the rate of actuation of each cylinder set, stroking each set to maximum extension will synchronize the pair. Flow divider-combiner valves do not work well when used in series with each other, thus the double pumpset was specified.

A gear type of pumpset was choosen to minimize cost. An open circuit was choosen to allow ample flow for temperature regulation. As this circuit is powered by a dedicated prime mover, little is to be gained by using a more costly closed-circuit system. A pumpset of 0.8 cubic inch per revolution per section was selected. At a pump speed of 2800 RPM, the wheels will be raised through the complete cylinder stroke in 38 seconds, and lowered in 28 seconds. This will allow the bottom of the barge to be raised from the ground to the maximum ground clearance position of 12 inches in 7 seconds and lowered back in 9 seconds, in the 12.5 tonnes cargo load condition.

A simple aluminum reservoir of approximately 30 gallon capacity will be required. This reservoir will include a 110 VAC low-density heater, for connection to a ship / shore supply for pre-heating of the hydraulic oil.

The prime mover for this circuit is specified as a Kubota D1402-B. This is a 3 cylinder diesel engine, with a total displacement of 85.13 cubic inches. Net intermittent horsepower (SAE J1349) is 28.5 Horsepower at 2800 RPM. This power will allow the maximum system pressure of 2500 psi to be reached at full hydraulic pump flow in both pump sections. (See Reference 6 for Engine Specifications).

1.15 CONSTRUCTION SEQUENCE

The barge has been designed to follow a specific sequence of construction.

The wheel housing assemblies (Reference drawing 108-22-R) are to be fabricated on a horizontal jig to ensure trueness. This is critical with respect to the sliding of the wheel assembly up and down the frame. The wheel housings, frames and longitudinal girders are then erected on a datum base in the inverted position.

The longitudinals are welded into position. Other components that assist is supporting the shell plating are welded in place to allow the plating of the hull to begin.

The sides and bottom are then plated up in a symmetrical sequence, to minimize distortion. On completion of plating, the structure is then removed from its datum base and turned over. Back welding of seams and fillet welding of section components is then completed.

On completion of all welding below the cargo deck level, the deck plate is to be fitted. Joints of the deck have been situated over the channel beams of the double bottom. This allows the upper flange of the beams to be used as a backing strip. Deck plating to longitudinals will be slot welded.

As the plating of the cargo deck progresses, other details will be worked on to complete the aluminum construction stage of the hull.

Once welding of the bottom is completed the UHMW bottom sheathing will be fitted.

The ramp/door is to be completed separately from the hull as it is a self-contained fabrication. It is to be fitted to the completed barge hull. Associated seals, tightening toggles and winches will be fitted at this time.

The wheel arrangements will be completed with the mounting of the axle carriages, installation of the hydraulic cylinders and hydraulic control system. Finally the wheels will be mounted on the axles.

2.0 GANTRY ARRANGEMENT

The arrangement of gantry is shown in Drawing 108-23-D. The gantry is designed to allow a 20 foot cargo container to be raised clear of the barge, thus allowing the barge to be removed. The lifting is to be done at the 4 corners of the container using hand operated 10 Ton chain hoists. The two main lifting wide-flange beams each have a 16 inch section, and are spaced 20 feet apart. These beams are elevated on columns 14 feet high. These beams and columns are held in position by numerous braces located for maximum support. All sections of the gantry are joined with pinned or bolted connections to allow easy disassembly for transportation. The material used in this gantry is structural steel made to CSA G40.21/M Type 300W specification, which has a yield strength of 44,000 psi. The maximum container weight allowed for lifting is 12.5 Tonnes. The gantry base consists of two 20 foot long by 6 inch wide skids. This large contact area allows the ground pressure to remain under 10 psi under maximum loading conditions, which is below the pressure exerted by the barge wheels when fully laden.

2.1 GANTRY - METHOD OF OPERATION

The ARKTOS/PABS/Gantry combination will be used on totally unequipped remote shorelines which have no docks or lifting equipment within a close proximity of the desired inland cargo discharge site. This gantry would also only be used with delicate cargo unable to be skidded off the PABS or when multiple loads have to be discharged quickly. For example more than 10 containers from a ship to shore. As the gantry must lift the container load and span the barge's wheels, it is, by specification, a relatively large piece of equipment. It is obvious that the design of such a gantry must take into account the method of its assembly when on a remote shore. Thus the method of operation consists of two critical components: assembly and operational sequence.

2.1.1 ASSEMBLY

On the first PABS load to shore, the dismantled gantry and a few pieces of assembly equipment would be skidded from the PABS deck. This part of the first load would include:

- 18 pieces of fabricated steel (See Drawing 108-23-d)
- 4 chain hoists
- a good supply of assembly bolts, shackles, locking container lifting points and blocks.
- several wrenches, pry bars, come-a-longs and other rigging tools.

1) The towing winch on the aft end of the ARKTOS would be used to pull both the skids into their respective positions next to each other.

2) Both end "goal posts" would be put together complete with their small corner braces, and pulled with the winch into position on the skids.

3) The four main pivot bolts at the bases of the "goal post" uprights would be loosely located.

4) The "goal posts" would be pulled/pivoted into the upright position one at a time. Once the posts were upright against their stops, the large side cross-braces would be lifted/pivoted and their bolts loosely located.

5) The top cross braces would then be loosely bolted in position using the ARKTOS' towing winch.

6) At this time all the bolts would be tightened and the chain hoists shackled in position.

2.1.2 OPERATIONAL SEQUENCE

The PABS would be towed under the gantry and the rest of the first load of cargo lifted off the deck. This lifting would be achieved by a combination of use of the manual chain hoists and the jackable wheels.

The ramp would be lowered again and the ARKTOS would pull the PABS from under the suspended load.

The ARKTOS/PABS combination would pull the gantry crane on its skids away from the cargo which would have been lowered onto the ground via the chain hoists.

The gantry would then be towed to a location which allowed access for the ARKTOS/PABS combination with its next load.

3.0 COST ESTIMATE

The design has been taken to the point that an accurate cost estimate of the materials required to build the barge can be made. An accurate material estimate has been made for all components. A summary of the estimate is listed in Reference 8. The cost estimate includes only the direct material portion of the construction of the barge.

Direct material costs for the prototype barge can be summarized as: (figures rounded to the nearest thousand)

Aluminum	$ 21,000
UHMW	$ 11,500
Wheel Ass'y and Tires	$ 38,500
Hydraulics	$ 17,500
Miscellaneous	$ 1,500
Total	$ 90,000

An estimate of the labour required to build the barge has been completed. It is anticipated that 143 man days would be required, with a workforce breakdown of:

Shop Foreman	15 man days x $515	=	$ 7,725
Cutter	30 man days x $415	=	$12,450
Welder	60 man days x $405	=	$24,300
Fitter	30 man days x $375	=	$11,340
Hyd. Fitter	8 man days x $425	=	$ 3,400
Total	143		$59,215

It is estimated that the total elapsed time to build the barge would be 10 weeks.

The prototype barge, and small quantity production of future barges will be built in aluminum. Future serially-produced barges will most likely be built of composite materials similar to those used in the construction of the ARKTOS vehicle. This would allow the barge concept to take full advantage of the superior performance of composite materials in arctic amphibious service over that of aluminum or steel. Tooling for a composite barge is not justified given the one-off nature of the prototype.

The material cost for the gantry has been estimate as:

Steel	$ 2,500
Hoists	$ 10,000
Miscellaneous	$ 2,000
Total	$ 14,500

4.0 WEIGHT ESTIMATE

A detailed weight estimate of the prototype barge has been completed and is included in Reference 7. It can be summarized as:

Aluminum	8,712
UHMW	2,375
Wheel Ass'y and Tires	6,528
Hydraulics	1,780
Miscellaneous	110
Total	19,505 lbs.

It should be noted that the material weights used in the cost estimate and the material weights used in the weight estimate differ. This is due to the waste material that occurs as a result of the manufacturing process. This results in more material being purchased than is actually fitted to the barge.

The weight of the gantry has been estimated at 5304 pounds.

Reference 7

\pabwgtru.wk1

Passive Amphibious Barge System (PABS)
Direct Material Weight Estimate

Material Description	Req'd SQ.FT	LBS./SQ.FT.	LBS.
Part 1 - Aluminum Plate			
PLATING 3/16"	450	2.64	1188
PLATING 1/4"	1054	3.52	3710
TREAD PLATE 1/4"	478	3.70	1769
PLATE 3/8"	11	5.29	58
PLATE 1/2"	29	7.00	203
PLATE 1"	4	14.20	57
Part 2 - Aluminum Section	LIN. FT	LBS/FT.	LBS.
SIDE FRAMES	89	1.29	115
BOTTOM FRAMES	126	1.99	251
CARGO DECK BEAMS	115	2.23	256
BILGE STRINGER	76	2.40	182
BOTTOM LONG	111	0.86	95
DECK LONGITUDINALS, ETC.	267	0.60	160
SHEATHING GUIDES	264	0.50	132
WHEEL HOUSING FRAME	68	6.50	442
MISC. SECTIONS	55	1.70	94
Part 3 - Hardware			
BOTTOM SHEATHING UHMW 1 1/2"			2375
WHEEL ASS'Y SLIDES UHMW 1/2"			128
WHEEL ASS'Y STEEL			2416
HUB ASS'Y/SPINDLE			200
RIM 4 @ 276 lbs			1104
TIRE 4 @ 670 lbs			2680
HYDRAULICS			
CYLINDERS			640
PUMPS			20
ENGINE			360
RESERVOIR, TANKS			500
VALVES			60
HOSE AND FITTINGS			200
MISCELLANEOUS FITTINGS			
RAMP WINCHES/SHEAVE/PENNANT			50
RAMP TOGGLES - ADJUSTING RATCHET			50
RAMP SEALS - NEOPRENE			10
TOTAL		(pounds)	19505
		Barge:	8.8

Reference 8

Passive Amphibious Barge System (PABS)
Direct Material Cost Estimate

Material Description	SQ.FT	LBS./SQ.FT.	$/LBS.	$
Part 1 - Aluminum Plate				
PLATING 3/16"	495	2.64	2.29	2992.57
PLATING 1/4"	1107	3.52	2.28	8884.34
TREAD PLATE 1/4"	524	3.70	2.82	5467.42
PLATE 3/8"	15	5.29	2.20	174.57
PLATE 1/2"	35	7.00	2.20	539.00
PLATE 1"	6	14.20	2.20	187.44
Part 2 - Aluminum Section				
	LIN. FT	LBS/FT.	$/LBS.	$
SIDE FRAMES	98	1.29	1.76	222.50
BOTTOM FRAMES	140	1.99	1.76	490.34
CARGO DECK BEAMS	127	2.23	1.76	498.45
BILGE STRINGER	84	2.40	1.61	324.58
BOTTOM LONG	123	0.86	1.61	170.31
DECK LONGITUDINALS, ETC.	293	0.60	1.61	283.04
SHEATHING GUIDES	290	0.50	1.76	255.20
WHEEL HOUSING FRAME	75	6.50	2.19	1067.63
MISC. SECTIONS	80	1.70	1.76	239.36
Part 3 - Hardware				
BOTTOM SHEATHING UHMW 1 1/2" 4' X 10' SHEETS X 10 @ $1075				10750.00
WHEEL ASS'Y SLIDES UHMW 1/2" 4' X 10' X 2 @ $341				682.00
WHEEL ASS'Y STEEL 2548 LBS. @ $/LB 2.29				5834.00
HUB ASS'Y/SPINDLE 4 @ $237				947.00
RIM 4 @ $3700				14800.00
TIRE 4 @ $4000				16000.00
HYDRAULICS				
CYLINDERS				3272.00
PUMPS				900.00
ENGINE				6789.00
VALVES				3284.00
HOSE AND FITTINGS				3000.00
MISCELLANEOUS FITTINGS				
RAMP WINCHES/SHEAVE/PENNANT				1000.00
RAMP TOGGLES - ADJUSTING RATCHET				250.00
RAMP SEALS - NEOPRENE				
TOTAL				89304.73

APPENDIX IV

Evaluation of Detailed Design

1. Mariport Group Ltd.
Evaluation of Sub-Tasks and PABS Concept Design

2. Watercraft Offshore Canada Ltd.
Response to Mariport

3. Mariport Group Ltd.
Conclusions

EVALUATION SUB-TASKS

3. EVALUATION SUB-TASKS

The evaluation has been conducted on the basis of the list of sources given in Annex 1. We have divided our commentary into two primary areas. The first is contained in Section a) through d) below. These sections follow the tasking by Canarctic in their letter of October 12th and reproduced in Annex 2.

More fundamental queries relative to the design are embodied in Section 4, which follows.

a) Fulfilment of Project Proposal Statement of Work

Reference is made to the Statement of Work dated June 12, 1990, Section 5. For convenience only abbreviated headings are provided.

STATEMENT OF WORK		FULFILMENT
5.2 a) Regulatory & Insurance Conditions	Regulatory	■ Contact has been made with ABS, who have indicated that they would class the unit. However, no information is available on what changes, if any, may be required. ■ Contact with CCG has indicated that the PABS unit is below the size limits at which CCG would be statutorily required to approve the design.
	Insurance	■ We are checking the figures reported in Phase 2.
b) Environmental Factors		■ Sea State (Sea Keeping) has been adequately covered. ■ Ice-water-ice has been addressed, but some questions remain. (Note 1)

NOTE 1: The tests apparently indicated a swamping tendency of the unit in the full 28 tonne displacement mode. This is to be expected given the present barge configuration. The tests conducted did not appear to meet the requirement regarding transfer in the towing or articulated mode.

3. EVALUATION SUB-TASKS - continued

STATEMENT OF WORK		FULFILMENT
		■ As reported, the overland tests are not considered to fully demonstrate land performance. (Note 2)
c) Performance Required,	Payload	■ Payload capability has generally been demonstrated, but see (Note 3).
	Operating Speed	■ Performance relative to speed in water is adequate performance relative to speed on land has not been demonstrated.
	Ease of Implementation	■ Not addressed. (Note 4)
d) Adaptability to the ARKTOS Vehicle		■ Presumed from the material reviewed, but not directly stated.
e) Shipboard Handling and Stowage		■ Addressed.
f) Ancillary Equipment		■ Addressed.

NOTE 2: The overland test report does not include typical Arctic terrain of muskeg or a rubble beach. Further, all tests were conducted on a level surface. No comment has been made as to whether the ARKTOS can sustain the towing resistances noted for wheeled and skidded operation or what these would be for typical grades. We presume that grade resistance could be calculated from the level results.

NOTE 3: Payload capability in the light and 12.5T design load have been demonstrated. However, a 20T design load in the present unit would put the mean water line well above the pontoon deck. This would require the stern ramp seals to be watertight. We do not believe the present unit can be assumed capable of handling a 20T load.

NOTE 4: To the extent any consideration has been given to operation, these appear to be idealized and not to relate to the conditions that may obtain in the Arctic.

3. EVALUATION SUB-TASKS - continued

STATEMENT OF WORK	FULFILMENT
5.2.1 Specification Review	An engineering specification has not been presented.
5.3 Conceptual Design and Supporting Calculations	A conceptual design has been produced.
a) Stress Analysis	■ No data provided.
b) Buoyancy, etc.	■ Completed.
c) Linkage System	■ Described only in very general terms.
d) Drag during over water operation	■ Completed.
e) Drag during overland operation	■ Not considered completed. See Note 2.
5.4 Model Tests	■ The S.O.W. required a 1/4 scale model to be tested. Actual tests were undertaken with a 1/5 scale model.
a) Overwater drag.	■ Generally complete, except for simulation of various cable lengths.
b) Overland drag.	■ See Note 2.
c) Inclining Tests	■ Carried out and compared with computer model results. (Note 5)
d) Sea Keeping	■ No quartering sea data provided, presumed an inadequacy of the test tank. Following sea data provided.
e) Ice/Water/Ice Stability	■ Carried out, but not in a test environment that simulated articulated link or cable towed modes.

NOTE 5: The Boeing computer model calculations do not appear to be consistent with the test conditions, or with each other. See Appendix 3, Task 3 Report.

3. EVALUATION SUB-TASKS - continued

b) Statutory and Classification Inputs

As noted Watercraft have made certain submissions to ABS relative to classing the PABS. ABS have responded with an approved stamped copy of drawing 108-8-R and covering letter (letter Sept. 4, 1990, W. G. Coulter).

We would wish to have confirmation that the drawing was not annotated by ABS in any way and that the original letter of submission covered the area of service and season for the unit.

With regard to CCG input, CCG have indicated that they would not be involved in approving the unit (letter July 24, 1990, Santos Pedro). However, the unit will be required to meet other statutory conditions.

c) Completeness of Design Submission and Suitability for Use as a Construction Specification

It is our opinion that the September 25th report by Watercraft does not constitute a construction specification. The accompanying drawings do not provide sufficient detail to permit construction to proceed without the need for substantial improvisation during the construction process.

Significant areas of omission are as follows:

- Hydraulic package and drive engine with exhaust and breathing arrangements.
- All watertight hatch arrangements.
- Ramp dogging arrangements.
- Reinforcement for towing points and container landing areas.
- Tie downs for cargo.

Areas that require more definition:

- Wheel assemblies.

d) Concerns Regarding Project

TDC have expressed one major concern:

- Ability to handle a 22.5 tonne payload and impact on the PABS and impact on its design.

3. EVALUATION SUB-TASKS - continued

Note that the TDC have variously mentioned 20 tonne and 22.5 tonne as the payload.

A standard 20 ft. ISO container is generally plated for 20 tonnes gross weight, which provides for a maximum 17/18 tonne payload. Newer containers are plated up to 24 tonnes maximum gross weight. Assuming a 20 tonne maximum gross weight and an 18,000 lb. light weight for the barge, the all up weight or full load displacement would be 62,100 lbs or 28.16 tonnes.

We do not believe that the present unit should be expected to handle heavier payloads than the 12.5t design. Redesign will, in our opinion be necessary to accommodate heavier loads.

Watercraft have also stated that it would be their intention to build production models in composite materials. This is probably appropriate, but would again require redesign.

COMMENTARY ON THE PABS CONCEPT DESIGN

4. COMMENTARY ON THE PABS CONCEPT DESIGN

We have extensively reviewed the drawings and material provided by Watercraft partly from an engineering/performance perspective, but mainly from an operational point of view.

4.1 Material

Aluminum has been selected as the construction material, presumably to meet weight requirements established in the S.O.W. However, if this is a trial vehicle to demonstrate the concept of the PABS rather than a prototype unit, then possibly steel would have been a better choice relative to ease of assembly and repair in the Arctic, as well as longevity in an ice/water/land operating environment.

If aluminum is to be used for construction, and given the operating environment and the intended use of the unit, we believe the scantlings are light. We would strongly recommend increased compartmentalization of the pontoon. To provide a degree of operational comfort. Each compartment can be provided with a small W/T inspection hatch. The compartments are too small for actual entry, so a large hatch is unnecessary.

4.2 Ramp

The design for the ramp is elegant, but given the operating environment of the barge presents some real risks. Assembly will also require to be very painstaking, to prevent warping. We would suggest in its place a simple reinforced plate assembly open on the back. We believe this could be made to achieve a watertight seal. We would question why, with a hydraulic drive in the barge, the whole ramp mechanism is not run by hydraulics.

4.3 Gantry

We do not believe that this will work as envisaged. The components are too large and heavy for easy field assembly. Further, no compensation is provided for uneven terrain.

We believe that if a gantry type crane is to be used then an aluminum lattice structure can be designed to handle the loads and be produced in component sizes that can be designed to handled by 2 persons. We would recommend that Watercraft contact companies experienced in providing rigging systems for rock concerts. The equipment concepts employed here, with light, but high strength components, air operated extension to working height and full compensation for uneven footing would be directly applicable to the PABS off loading system.

4. COMMENTARY ON THE PABS CONCEPT DESIGN - continued

Alternative concepts will be provided if deemed necessary by Canarctic. Actual operation of the gantry for container removal should be top lift not bottom lift through hooks in the corner castings. Other components can be slung.

4.4 Wheel Assembly and Hydraulics

The wheel assembly is a key area relative to barge operation. We are concerned that the schematic drawings provided do not demonstrate a rugged assembly. For example, there is no detailed rim assembly, although the tyre specified presumably fits an off the shelf rim. The rim assembly as shown is far too weak given the operation conditions.

A metal fillet is shown providing vertical stiffness, however horizontal fillets should also be included to accommodate racking stresses as the barge is pulled over obstacles or during turning.

We would like to see a statement that the hydraulics will be capable of elevating the full AUW of the barge to the maximum 12" ground clearance.

4.5 Lift On/Lift Off Ship

Given that the unit is intended to be lifted, by spreader, from a single hook, and given that the shackle points are relatively close to the centre of the barge, great care will be needed to ensure that loads are balanced. If possible the wheels and these attendant support structures should be moved fore and aft on the barge to give a better load distribution.

As the spreader will be shackled to the barge, this means that when the unit is in the water a person or persons will be required to negotiate around the coaming to hook up/off. This will be a dangerous procedure and lifelines will have to be rigged as there are no grab points. It may be impossible in anything other than purely nominal sea conditions.

When handling anything other than the first load off/last load in, spotting cargo – particularly a container – into the barge may be difficult. Loading/discharging may have to be undertaken on deck, which will slow operations down considerably.

4.6 Fendering

No fendering for lighterage operations is shown or suggested. Tie down points for portable fenders, or a heavy D section around the upper hull may be appropriate.

Watercraft
Offshore Canada Ltd.

October 30, 1990

Watercraft Offshore Canada Ltd.'s Response to the Mariport Group's Review of the ARKTOS-PABS Concept and Detailed Design Work.

This response will refer to the Section Numbers as those of the Mariport Group's report titled "Design, Development and Testing of the ARKTOS Passive Amphibious Barge System Task #4 Report Detailed Design", dated October 1990.

1 INTRODUCTION

1 No response required for Introduction

2 EXECUTIVE SUMMARY

2.1 Section 5.5 of the TDC Work Statement of 12 June 1990 required the Detailed Design phase of the project to provide drawings with sufficient details to permit eventual construction of a prototype barge. This has been completed.

2.2 See 2.1

2.3 See following sections for detailed response.

2.4 Watercraft disagrees.

3 EVALUATION SUB-TASKS

3 a) Fulfillment of Project Proposal Statement of Work

5.2 a) A copy of the complete ABS drawing which had no request for changes, has been provided. Watercraft sent a preliminary drawing to ABS for discussion purposes, which limited the need for changes to the final drawing submitted.

5.2 b)i. NOTE 1: Model tests were conducted through to 28 tonne displacement to determine limiting conditions. Limited ingress of water over the bow when the barge went from an ice step into water was noted. No ingress of water at the 12.5 tonne cargo design condition was noted.

5.2 b)ii. NOTE 2: Gradability curve and associated explanatory notes of the ARKTOS-PABS is provided.

5.2 c)i. Payload NOTE 3: Taken into consideration was the constraint of the ARKTOS vehicle planned for use with this barge. The Coast Guard Vehicle ARKTOS Beta was not designed as a towing vehicle and has a towing capacity lower that that of other ARKTOS vehicles. Thus the end product would be a prototype barge which would allow for a complete test program, plus would be able to be put into immediate service. The barge, as designed, can structurally handle a fully loaded (20 tonne) container. In the water, the loadline would be above the ramp seal, and the seal will be required to be watertight to keep the water from flooding the deck. This ramp seal therefore requires special attention as it is extremely important for the barge to operate at this load. The wheels are also important at this displacement to provide adequate stability to the barge. Watercraft would strongly recommend that the wheels not be removed from the barge at any time during testing for stability reasons.

5.2 c) ii. Operating Speed: For more detail on the land speed performance, see the supplied Gradability Curve.

5.2 c) iii. Ease of Implementation NOTE 4: Although there are always scenarios which will make some operations difficult or impractical, the prototype nature of the system must be acknowledged and accepted. Testing of a prototype always indicates improvements which could be made to the design, to improve the method of operation or a specific performance factor.

5.2 d) Adaptability: The study has indicated the barge will be connected to the ARKTOS by way of a winch at all times. A rigid tow bar or linkage is not required.

5.2 e) Shipboard Handling: No response necessary.

5.2 f) Ancillary Equipment: No response necessary.

5.2.1 Specification Review: The Specification Review was completed. An engineering specification was not part of this project. The drawings and specification supplied has proved the practicality of the design by receiving ABS approval.

5.3 Conceptual Design and Supporting Calculations

5.3 a) An analysis of the strength of various components of the barge was done during its design. The various design loadings exerted upon the barge from its cargo, the ice, land or water have all been considered at different times. The barge was structurally designed to carry a fully loaded 20 foot container. The ABS consideration of the barge considered in detail the scantlings of the barge carrying a fully loaded 20 foot container, which were the result of Watercraft's stress analysis.

5.3 b) Buoyancy: No response necessary.

5.3 c) Linkage System: See 5.2 d) The simplest connection between the barge and the towing vehicle will be by use of the winch.

5.3 d) Drag during over water operation: No response necessary.

5.3 e) Drag During overland operation: See Gradability Curve.

5.4 Model Tests: The Model test plan detailed the requirement of the test tank to use a 1/5th scale model rather than a 1/4 scale model. This test plan was approved prior to testing.

5.4 a) Overwater drag: Towlines were used to determine directional stability, rather than hull resistance. The single towline length with bridle was used as a standard test procedure. The barge exhibited such excellent directional stability that the test tank personnel suggested that further tests were not required.

5.4 b) Overland drag: See Gradability Curve.

5.4 c) Inclining Tests (NOTE 5): The purpose of inclining the model was to confirm two components of the computer prediction: the hull definition component and the calculation component. The VCG of the unballasted model was different than that planned for the prototype. This was determined by inclining the model in air. A set of computer predictions were done to simulate the tests done with the model. As the correlation between the predictions and the model tests were excellent, both components of the computer model were confirmed as accurate.

5.4 d) Sea Keeping: Agreed.

5.4 e) Ice/Water/Ice Stability: The model was pulled from water onto the simulated ice step by using a come-a-long. Thus the cable towed mode, which is the anticipated mode of operation, was simulated. The barge was pushed into the water from the ice step. This removed the effect of the tow wire on the bow of the barge when it entered the water, thus presenting the worst-case of the barge being completely free to pitch when going from ice to water.

3 b) Statutory and Classification Inputs: Agreed

3 c) Completeness of Design Submission and Suitability for Use as a Construction Specification
See 2.1: Section 5.5 of the TDC Work Statement of 12 June 1990 required the Detailed Design phase of the project to provide drawings with sufficient details to permit eventual construction of a prototype barge. This has been completed.

3 c) i. Hydraulic package: See drawing 108-25-B, "Hydraulic Power Pack"

3 c) ii. Watertight Arrangements: Deck hatches are relatively simple details that are subject to ABS inspection and approval.

3 c) iii. Ramp dogging Arrangements: Detailed on Construction Drawing 108-8-R, and subject to ABS inspection and approval.

3 c) iv. Reinforcement for towing points and container landing areas: For towing points, see Drawing 108-14-D. For container landing areas, see Drawing 108-8-R, items 25 and 26. ABS

specifically requested that the landing areas for the container be detailed prior to their receipt of this drawing. ABS considered the deck loading to be a fully loaded 20 foot container in their consideration of the scantlings of the barge.

3 c) v. Tie downs for Cargo: Tie downs for general deck cargo to be pad eyes located at each frame, near deck level. A total of nine pad eyes each side would be provided.

3 c) vi. Wheel Assemblies: Drawing of Assembly Provided.

3 d) Concern Regarding Project: The structure of the PABS has been designed to withstand the load of 22.5 tonne payload. This has been considered both as a distributed load and as a 4-point load as from container corners. Loading the barge to 22.5 tonne payload in the water would lower the main deck below the waterline, and decrease the stability of the barge. The barge has been designed to handle the 12.5 tonne payload with a payload CG at the half-height of the container. This does not limit the capability of the barge to handle heavier loads on land, or for future barges to handle heavier loads in the water should testing prove it desirable.

4. Commentary of the PABS Concept Design

4.1 Material: The barge is aluminum to allow for ease of construction, in-field repair by welding, and relative light weight. Making the barge of steel would decrease the load-carrying capacity of the barge dramatically. Although it would make for very safe tests, the utility of the barge once through the test program would be extremely marginal. A light construction with a high degree of hull watertight subdivision and the addition of 1.5 inch thick plastic material to the outside of the hull should provide ample protection to the barge. If required, aluminum can be relatively easily repaired in the field using either inert gas, or temporary repair using stick welding techniques. ABS has approved of the scantlings and are aware of the intended use. ABS has indicated in discussions that ice classification for a barge of this type would be impractical. They note that the ATL and NTCL barges used in the MacKenzie River into Tuktoyaktuk are not ice classed.

4.2 Ramp: The Moment of Inertia of the ramp required to provide adequate strength and stiffness is achieved by closing in the back section, rather than leaving it open on the back. The ramp is raised by a hand crank in order to keep its mechanism as light and as simple as possible.

4.3 Gantry: Watercraft disagrees with this statement. There are several solutions to any engineering problem and we believe ours solves it in a cost-effective manner.

4.4 Wheel Assembly and Hydraulics: The rims to be provided with the wheels are not off-the-shelf, as the use of tires of this size is relatively limited. The rims would be fabricated by a rim-specialist to a commercially standard design. The rim has been shown as a plate to simplify the drawing, but stiffening would be provided by the manufacturer, to allow the rim to handle the design loads of the rim/tire combination.

The metal fillet will be modified to allow for more stiffness to accommodate racking stresses.

Each of the four hydraulic cylinders have a 4 inch diameter bore, and 2 inch diameter rod. The annular area of each cylinder is 9.42 sq. in., giving a total lift area of 37.7 sq. in. At a working pressure of 2000 psi, this allows for a total theoretical lift of 75,398 lbs., or 34.21 tonne.

4.5 Lift On/Lift Off Ship: The barge is intended to be lifted by spreader. The wheels are placed longitudinally on the barge to allow the barge to turn when towed on land.

We note the other comments from within this section.

4.6 Fendering: It is intended that the tires act as fenders, or that fendering would be done off the mother ship, as the barge would not want to carry heavy fenders to and from the shore. If required to operate the barge without the tires, fendering can be addressed easily. The requirement to operate without wheels would have to come as part of the construction phase of the PABS development.

THE MARIPORT GROUP LTD.

MULTIMODAL ADVISORY SERVICES TO THE TRANSPORTATION, MARINE AND PORT INDUSTRIES

October 31, 1990.

Mr. W. R. Mann,
Manager, Technical Services,
Canarctic Shipping Company Ltd.,
350 Sparks Street, Suite 1005,
Ottawa, Ontario.
K1R 7S8

Dear Mr. Mann

Re: ARKTOS-PABS

Further to your memorandum of October 30th, outlining Watercraft's response to our earlier concerns about the concept and detailed design work, we note that Watercraft have been able to address most of our concerns by providing additional detail to the drawings and documents reviewed.

We had interpreted the requirement to be that Watercraft should provide adequate specification and detail design to permit construction to proceed. If, as you indicate in 2.1, the requirement is to provide drawings with sufficient detail to permit eventual construction of a prototype barge, then we can accept the material provided by Watercraft as adequate. However, given the exchanges that have taken place, and the acceptance that both drawings and specifications are not fully detailed, we would urge Watercraft to review their construction estimates to ensure that they have covered all material, subcontract, labour, drawing office, and regulatory costs, including an adequate contingency.

We still have some differences of opinion, but these should not prevent the project proceeding.

Yours sincerely,

THE MARIPORT GROUP LTD.

Christopher Wright
per Ja

CW/ja

Christopher Wright,
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APPENDIX V

Stability Review
Watercraft Offshore Canada Ltd.

November 28, 1990

Stability Review

Stability calculations were done for the barge using the Boeing Computer Services "Shiphull" program. The design conditions included the following assumptions:

Weight of empty barge	7.13 tonne
Weight of wheels	1.72 tonne
Weight of barge with wheels (Light Ship)	8.85 tonne
Payload (10 tonne cargo + 2.5 tonne container)	12.50 tonne
Weight of fully loaded barge	21.35 tonne

VCG of payload at 1/2 the container height.

The goal of the stability review was to investigate the effects on barge stability of:

a) the wheels
b) ramp seal failure
c) compartment damage
d) free surface effects
e) cargo shift.

2) Waterlines

The properties of form were calculated for the fully loaded barge, with and without wheels. As the wheels are free of the waterline by 12 inches, they have no more effect on the properties of form at zero list and trim, than to lower the barge in the water by 1.5 inches and thus slightly increase the waterplane area. Table 1 summarizes the waterlines in fresh and salt water at design displacment. The design displacement of the barge at 12.5 tonnes cargo load in salt water is equivalent to 12.0 tonnes in fresh water.

Table 1

Condition	Salt Water Draught (in)	Salt W. Freeboard (in)	Fresh W. Draught (in)	Fresh W. Freeboard (in)
Wheels up, 12.5 tonne cargo	25.4	2.6	25.8	2.2
Wheels off, 12.5 tonne cargo	23.6	4.3	24.4	3.6
Load to deck level 14.3 tonne cargo	28.0	0.0		
Wheels on, 12.0 tonne cargo			25.4	2.6

In all cases, freeboard was measured from the top of the deck, assuming the seal to be non-functional.

3) Static Stability

A number of different static stability calculations were completed to demonstrate the characteristics of the naked hull, the barge with wheels, and the barge with an intact ramp seal. These calcualtions are summarized in Graphs 1 through 5.

3.1) Barge with Seal and Wheels

Graph 1, "Intact Seal, Various Wheel Conditions" was constructed from calculations which assumed the ramp seal was intact. As expected, the maximum GZ of the barge decreases as the wheels are raised or removed. Removing the wheels has a dramatic effect, lowering the maximum GZ from 2.15 feet to 0.75 feet.

3.2) Barge without Seal

The computer model of the barge was re-structured to determine the effect of removing the seal. This model allowed for loss of waterplane area as the barge heeled and water flooded over the deck. The model assumed the ramp was missing. Graph 2 "With Wheels, With And Without Seal" demonstrates the loss of stability associated with the loss of the seal with the wheels in the raised position. The maximum GZ is decreased by approximately 40% when water is allowed to freely flood the deck. The lower of the two curves indicates the expected normal in-water operating condition of the barge, that with a non-functioning seal and the wheels in the raised position. This produces a maximum GZ of 0.95 feet, and an angle of vanishing stability of 58 degrees, well beyond the point of deck edge immersion.

If the barge was to be operated fully loaded with 12.5 tonnes cargo (VCG at half-container height) without its wheels, the seal becomes very important in maintaining adequate barge static stability. This is depicted in Graph 3 "Without Wheels, With And Without Seal." The maximum GZ drops approximately 80% when the ramp seal is removed from the barge without wheels.

3.3) Barge Without Wheels

As already shown, the effect on static stability of removing the wheels from the barge is dramatic. Ignoring the seal, the stability of a fully loaded barge without wheels becomes very marginal. The effect of removing the wheels in this condition is shown in Graph 4 "Without Seal, With Wheels Up Or Off." Removing the wheels drops the maximum GZ by 80%, ignoring the seal.

In this condition, the effect of adding load, assumed to act at the 1/2 height of the container, is demonstrated in Graph 5, "Without Wheels/Seal, Different Displacements." This curve shows that the light ship stability without wheels is relativly high, and therfore it may be possible to operate the barge under certain load conditions without the wheels in place.

In the normal water operation of the barge, the wheels are to be raised to minimize drag of the barge. In the worst case, as far as stability is concerned, the wheels would be raised to the top of their range. This has the combined effect of raising the VCG of the barge, as well as lifting the bottom of the wheels 12 inches above the design water line, where the wheels' effect on stability is delayed. At the fully raised position, the wheels do not affect stability until 6 degrees of roll.

4) Dynamic Stability

As an indicator of dynamic stability, the area under the GZ curve, from level heel to the angle of deck edge immersion, has been calculated and is presented in Table 2.

Table 2
Area Under GZ Curves (ft.degrees)

Displacement	Seal Cond'n	Wheel Pos'n	Area
12.5 tonne cargo	intact	low	61
12.5 tonne cargo	intact	high	37
12.5 tonne cargo	intact	off	19
12.5 tonne cargo	damaged	high	14
12.5 tonne cargo	damaged	off	4
Light Ship	damaged	off	135

Table 2 highlights the effect of removing the wheels on the stability of the barge.

5) Free Surface Effect

Due to the large deck area of the barge, the free surface effect of shipped water was investigated using the following assumptions:

-sufficient water is shipped to lower the barge deck level to waterline.

-permeability of the barge deck is 1.00. This maximizes the free surface effect, as the container or any other cargo on the barge deck which would decrease the free surface effect is ignored.

-the ramp seal is in place, holding all water on the deck.

-the wheels are off of the barge.

The free surface effect was treated as a correction factor to KM. Calculations indicated that the large area of the deck results in a very large free surface correction factor at level heel, which results in the initial GM of the barge to be negative. As the barge heels, the free surface of the retained water decreases as it collects on one side of the barge. In this condition, the free surface effect resulting from four inches of water on the deck will cause the barge to heel approximately 7 degrees.

6) Damaged Stability

The barge hull has been subdivided into seven compartments. Damaged stability was tested for damage of one compartment. Damaged buoyancy has been calculated to be sufficient to float the barge with at least any two compartments flooded, assuming 100% permeability of the tanks. Damaged stability was determined at different possible operating conditions at the perceived two worst damaged conditions: damage of the stern quarter compartment (Comp. E) and damage of the forward compartment (Comp. A).

The effects of permeability were considered as part of the damaged stability investigation. Initial calculations were done at 100% permeability, allowing the compartments to fill completely with water. Further calculations were done assuming the compartments were filled with spheres approximating ping-pong balls, resulting in a permeability of 25%. All calculations were done assuming the seal was damaged and the deck free to flood. The calculations were done with the wheels in the raised position, and off the barge.

6.1) Effect of Wheels

The wheels provide great amounts of buoyancy and righting movement to the damaged barge. Comparing Graphs 6, "Damaged Stability, With Wheels, No Seal", and 7, "Damaged Stability No Wheels, No Seal, for the 100% permeability case, the wheels can be seen to stop the loaded barge from capsizing. With the wheels, (Graph 6) the stern damage results in an angle of lull of 17 degrees and the bow damage one of 6 degrees. See Diagram 1 for damaged flotation lines. Removing the wheels from these damaged barges removes the remaining righting moment and the barge capsizes (Graph 7).

This condition can be improved with the filling of the compartments with a material which provides a minimum of 25% permeability. The 25% permeability case is shown in Graph 8, with wheels, and Graph 9, without. With this material, and the wheels, the stern damage results in an angle of loll of 5 degrees (wheels contact water) and the bow damage one of 7 degrees. (See Diagram 2 for damaged flotation lines with 25% permeability). Both curves maintain a good positive GZ beyond these angles of loll. Removing the wheels, however, changes the characteristics of the curves completely. The bow damaged condition has positive GZ through to 25 degree heel. The stern damage condition does not quite reach the positive righting arm and would capsize. If it was deemed necessary to design the barge to remain stable without the wheels in this damaged condition, final permeability of the compartments would have to be choosen to be less that 25%.

7. Cargo Shifting

The effects of cargo shift were calculated assuming the cargo was a container, and that it could shift to the outboard extremes of the barge. This translates into a 2.25 foot forward shift, a 1.00 foot outboard shift, and a 4 foot aft shift. Barge conditions were checked with and wihtout the seal and with and without the wheels. The conclusions are summarized in Table 3.

Table 3
Shifting Cargo Effects

	Final Attitude
Forward Shift	2.38 inch trim bow down
Aft Shift	21.3 inch trim bow up
Outboard Shift, With Wheels and Seal	12 degree roll
Outboard Shift, With Wheels, Without Seal	19 degree roll
Outboard Shift, Without Wheels, With Seal	14 degree roll
Outboard Shift, Without Wheels, Without Seal	Barge Capsizes

Trim is defined as difference in height between waterlines at the aft a forward perpendiculars.

These calcualtions confirm that the barge sould be operated with its wheels when carrying a 12.5 tonne load.

8) Effect of Raising Deck Height

As a result of concerns raised over the dependability of the seal, and the effect of the loss of that seal on the stability of the barge. A further set of calculations were completed to determine the effect of raising the deck height, and thus increasing the freeboard of the barge.

The deck height was raised in 3 steps of 4 inches each. Although the stability of the barge would be decreased at larger angles, due to the increased VCG, the lower angle stability would be improved, as the ingress of water onto the deck would be delayed with the higher freeboard.

The results of these calculations are presented as Graph 10, "Hydrostatic Stability, With Wheels" and Graph 11, "Hydrostatic Stability, Without Wheels". It can be seen that in all cases the low angle stability increases with deck height. The loss of higher angle stability must be considered with respect to the increased freeboard and therefore operational freedom that raising the deck would provide.

Again, as an indicator of dynamic stability, the area under the GZ curve, to the angle of deck edge immersion has been calculated and is presented in Table 4.

Table 4
Area under GZ Curve (ft. degrees)

Deck Height:	Datum	+4"	+8"	+12"
Wheels Up	14.4	13.9	14.7	14.9
Wheels Off	3.6	3.1	4.5	5.2

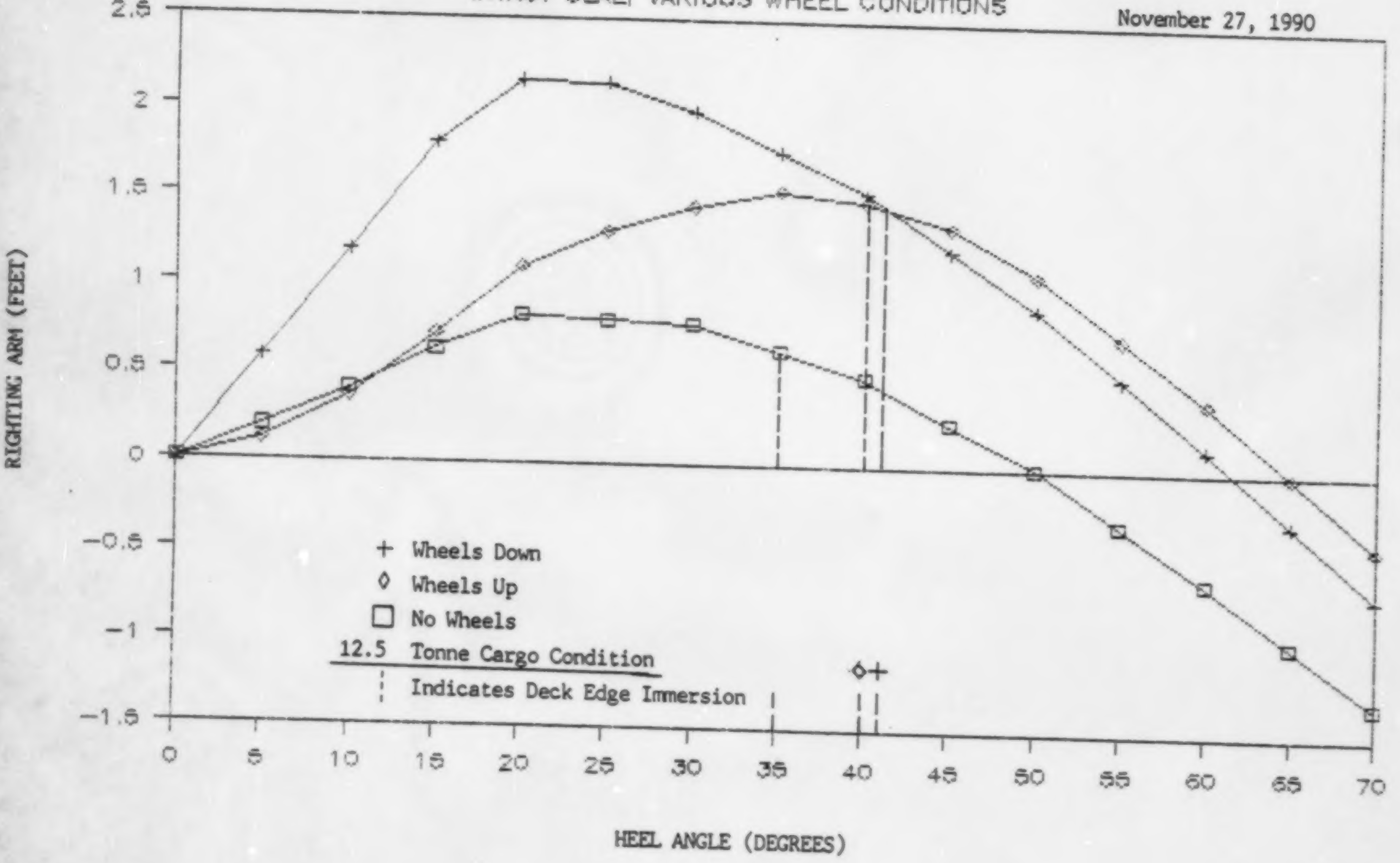
It is shown that the area decreases with the initial increase of 4 inches. The area is more than made up in both cases by the increase to 8 inches. In both cases, increasing the deck height by 6 inches would provide the same area under the GZ curve as the datum conditions, but with the added benefit of increasing freeboard to approximately 10 inches at the design water line.

GRAPH 1

HYDROSTATIC STABILITY

INTACT SEAL, VARIOUS WHEEL CONDITIONS

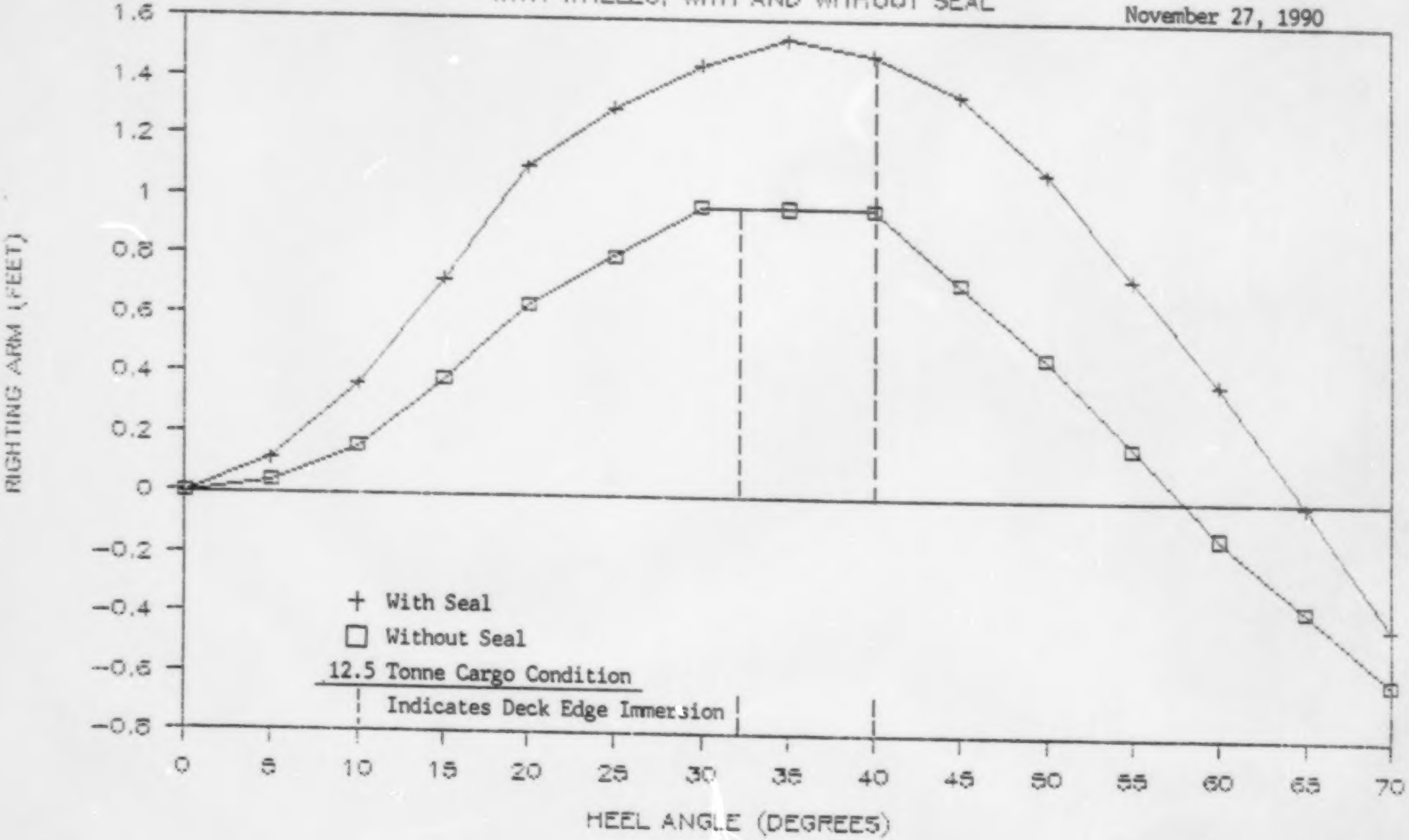
November 27, 1990



GRAPH2

HYDROSTATIC STABILITY

WITH WHEELS, WITH AND WITHOUT SEAL

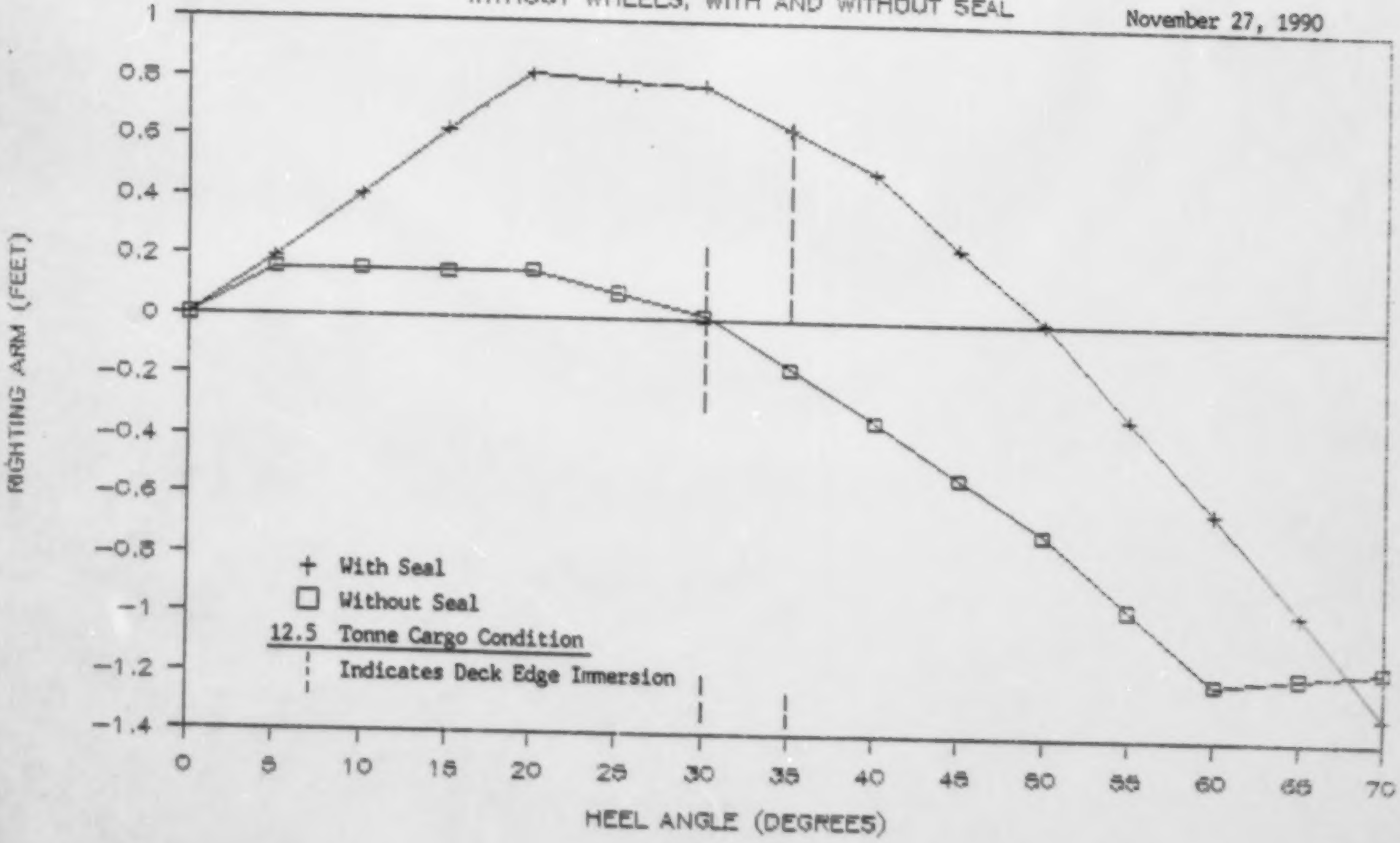


GRAPH 3

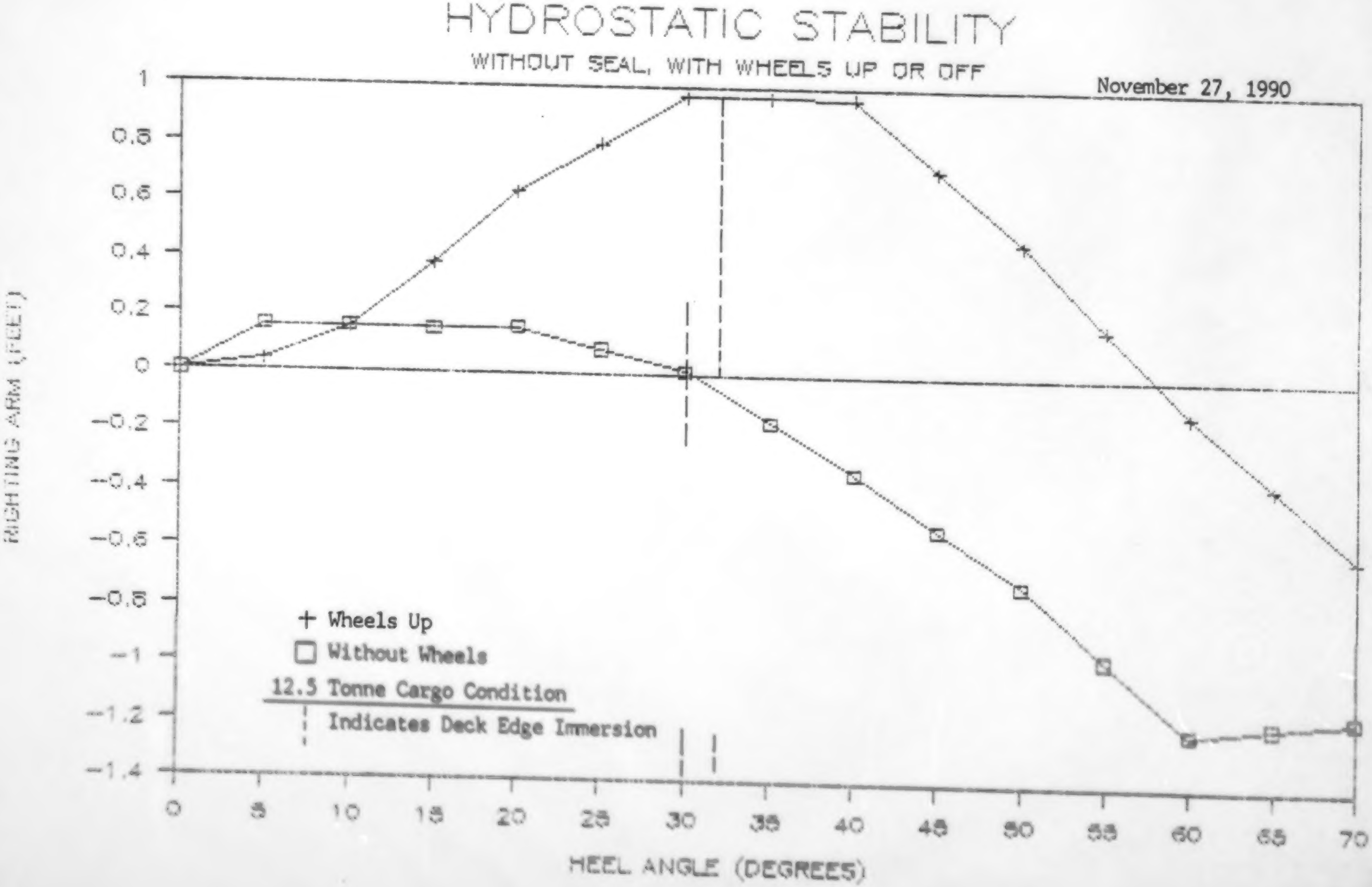
HYDROSTATIC STABILITY

WITHOUT WHEELS, WITH AND WITHOUT SEAL

November 27, 1990



GRAPH 4



HYDROSTATIC STABILITY

WITHOUT SEAL, WITH WHEELS UP OR OFF

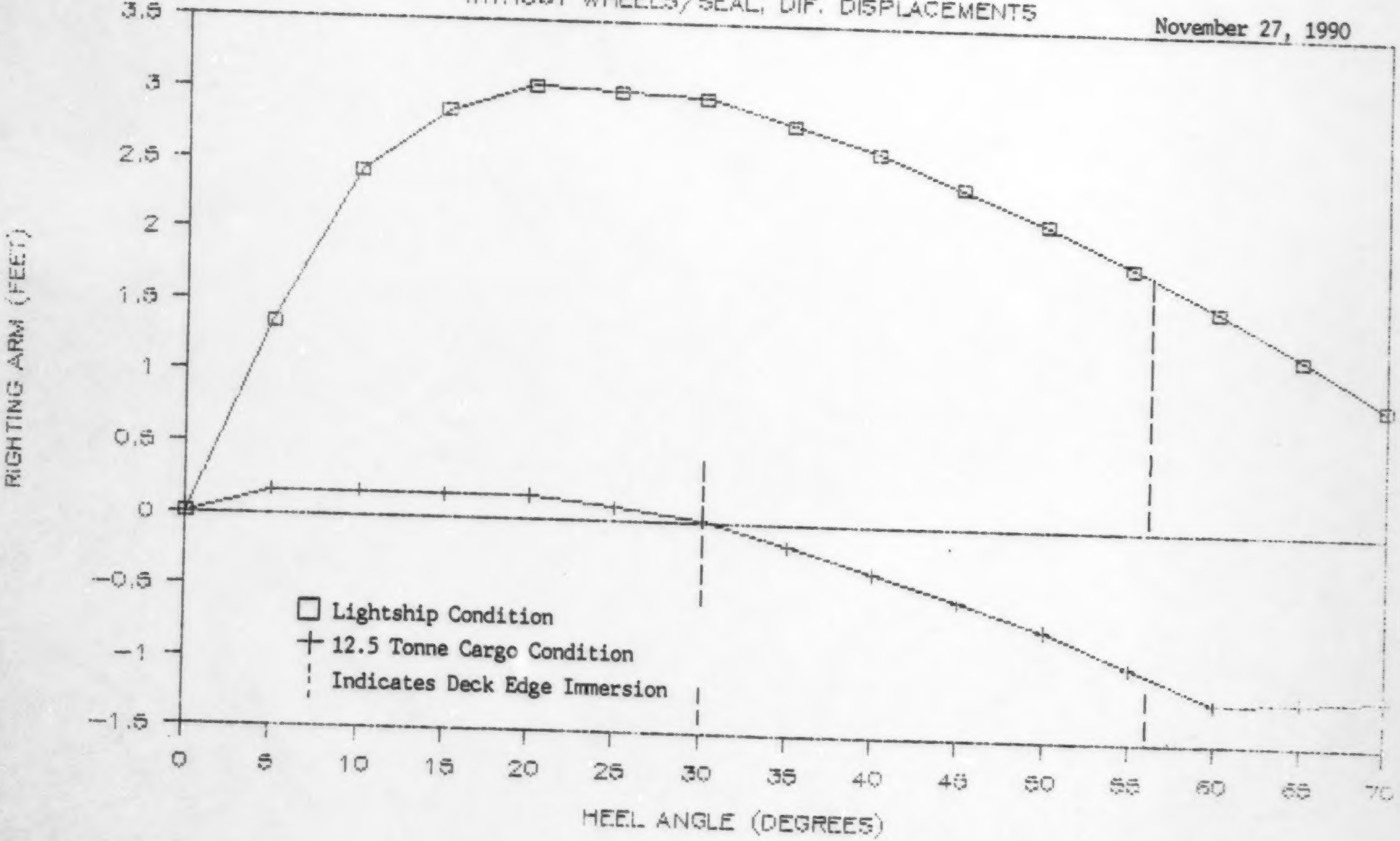
November 27, 1990

GRAPH 5

STATIC STABILITY

WITHOUT WHEELS/SEAL, DIF. DISPLACEMENTS

November 27, 1990

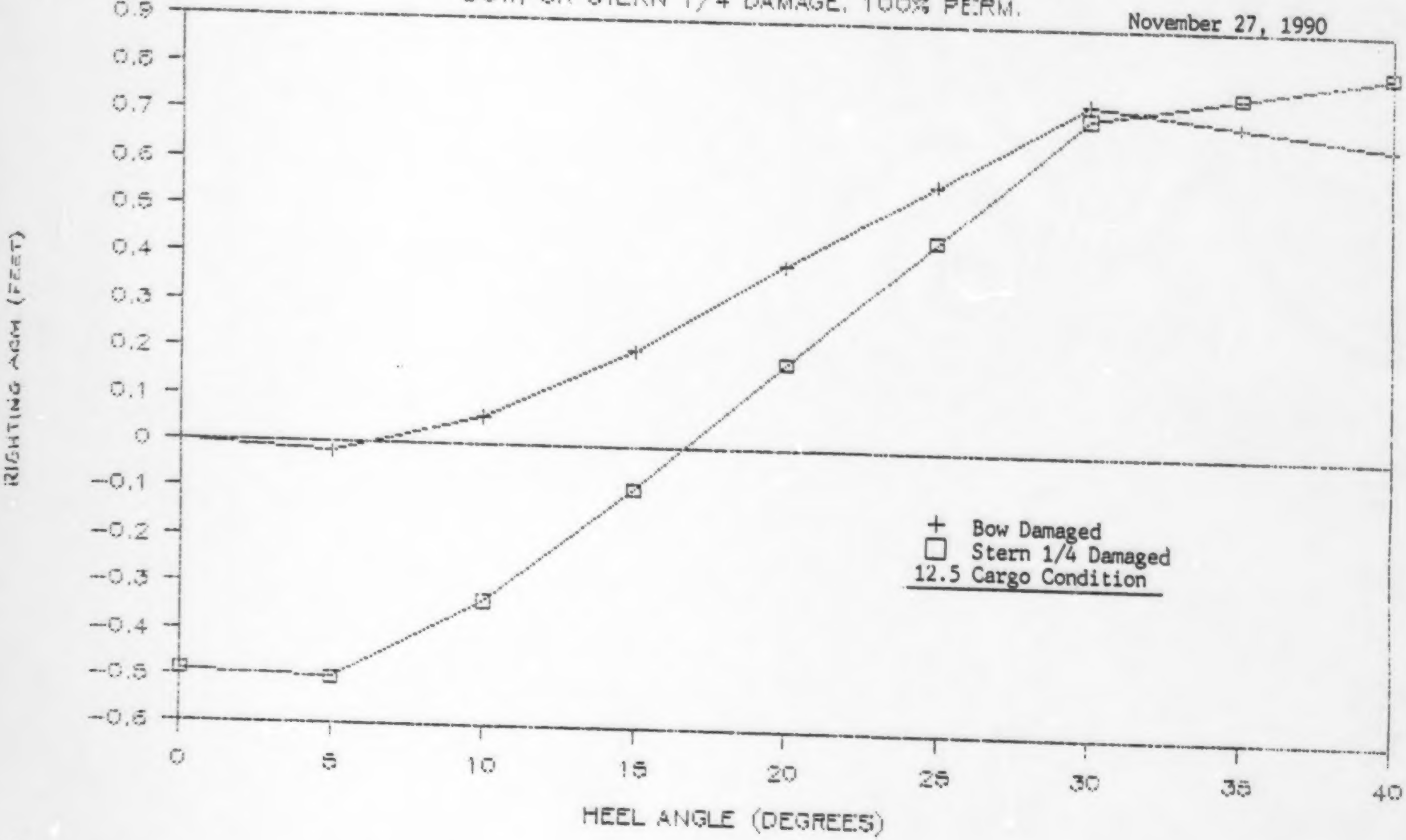


GRAPH 6

DAMAGED STABILITY, WITH WHEELS, NO SEAL

BOW, OR STERN 1/4 DAMAGE, 100% PERM.

November 27, 1990

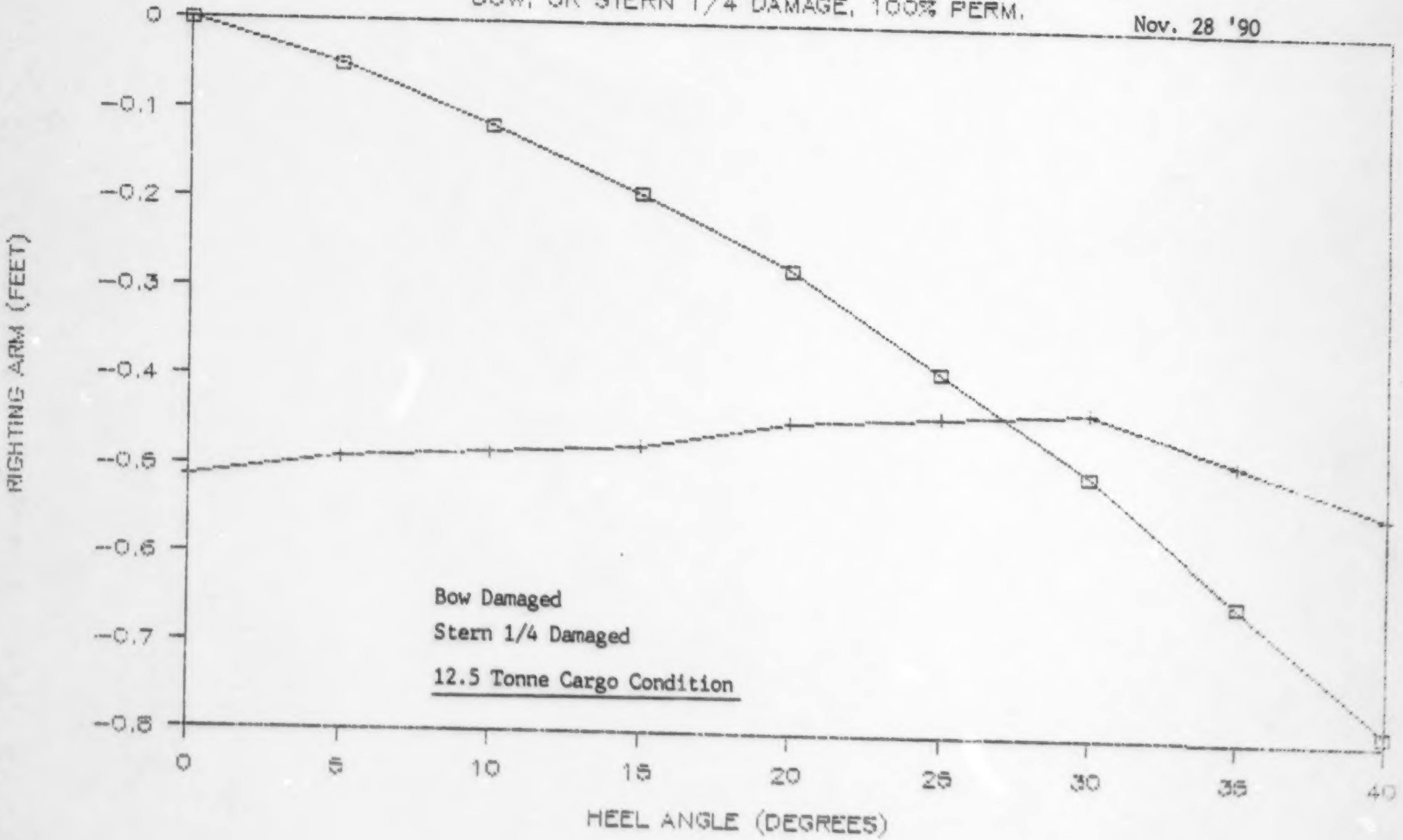


GRAPH 7

DAMAGED STABILITY, NO WHEELS, NO SEAL

BOW, OR STERN 1/4 DAMAGE, 100% PERM.

Nov. 28 '90

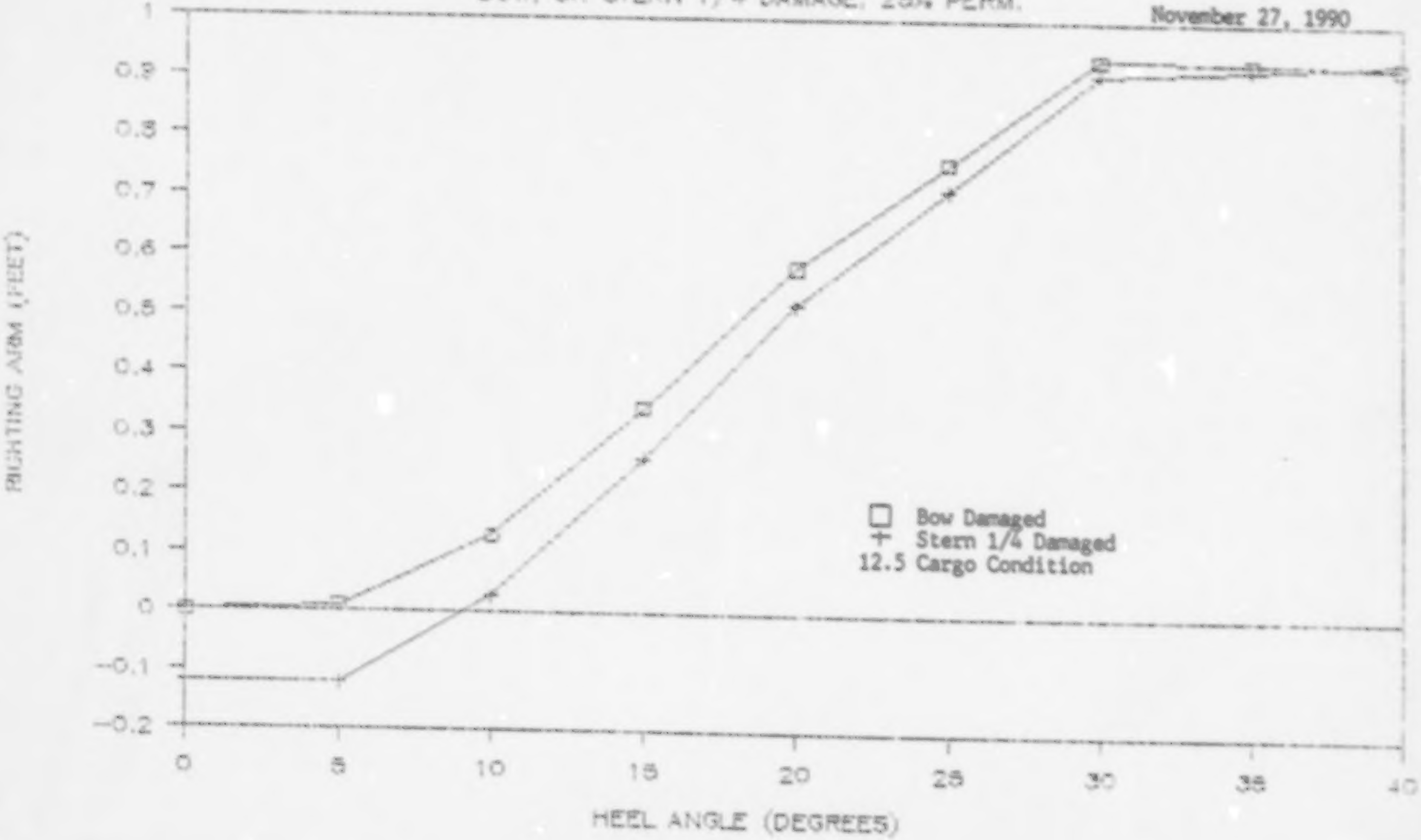


GRAPH 8

DAMAGED STABILITY, WITH WHEELS, NO SEAL

BOW, OR STERN 1/4 DAMAGE. 25% PERM.

November 27, 1990

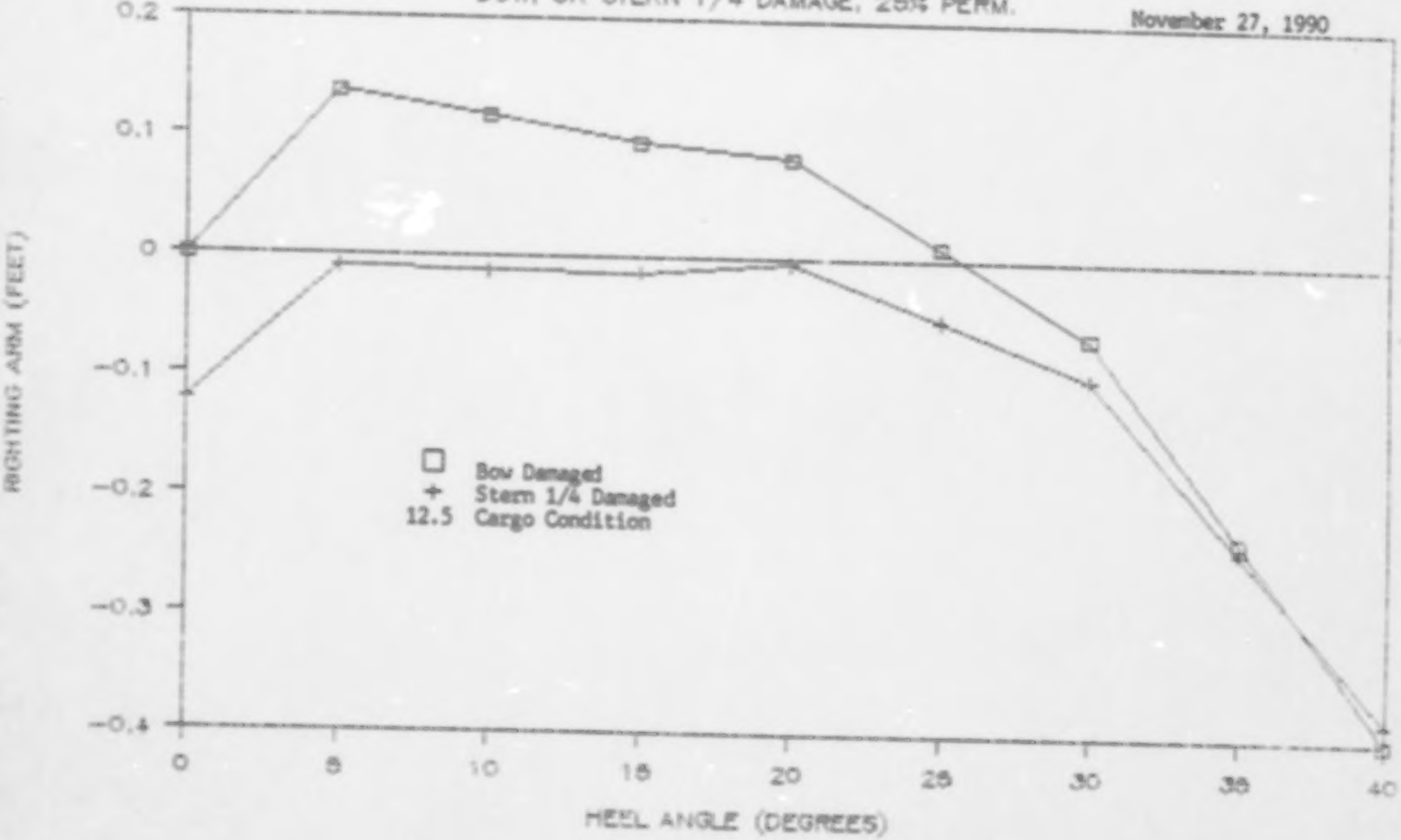


GRAPH 9

DAMAGED STABILITY, NO WHEELS, NO SEAL

BOW, OR STERN 1/4 DAMAGE, 25% PERM.

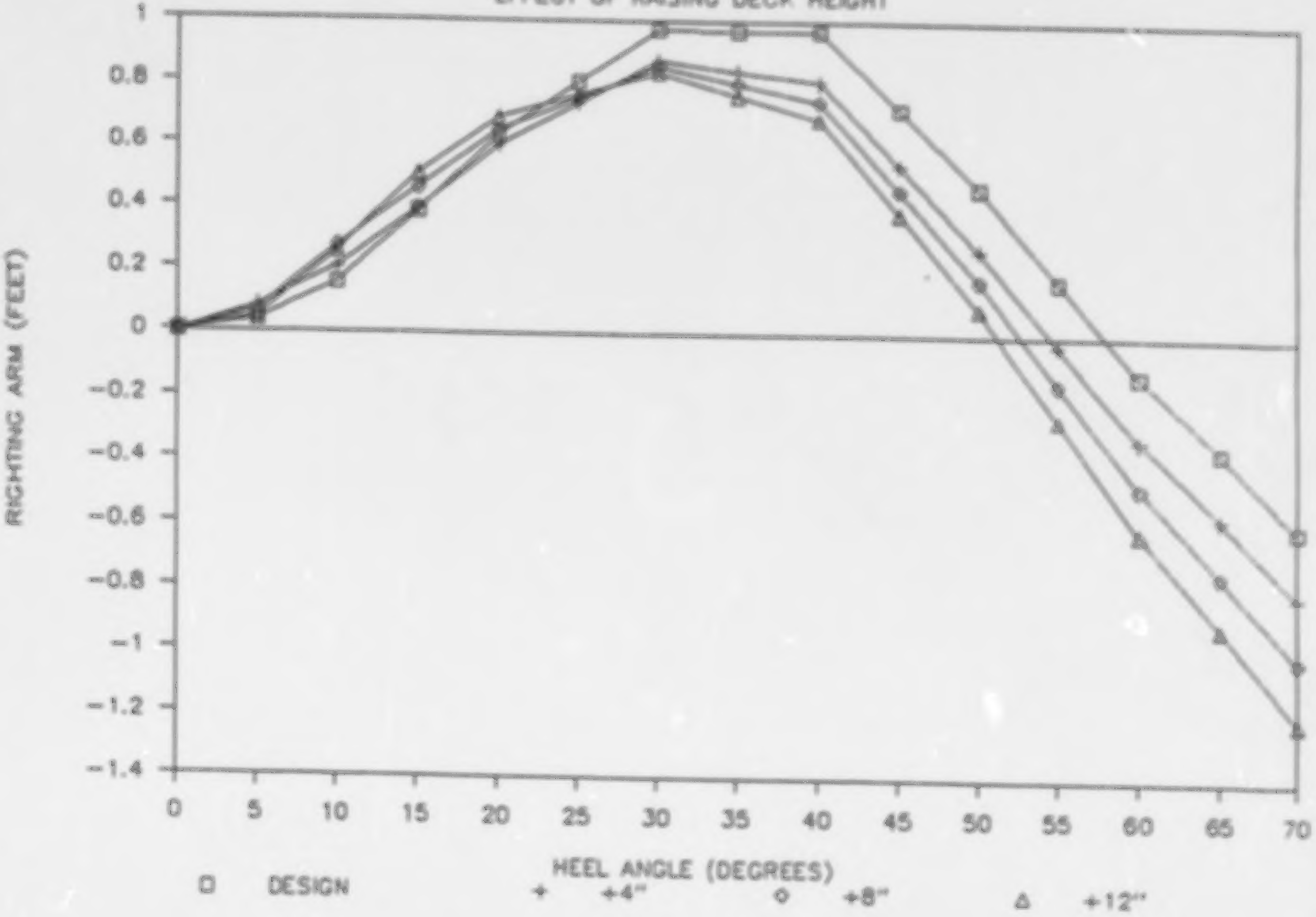
November 27, 1990



GRAPH 10

HYDROSTATIC STABILITY, WITH WHEELS

EFFECT OF RAISING DECK HEIGHT



GRAPH 11

HYDROSTATIC STABILITY, WITHOUT WHEELS

EFFECT OF RAISING DECK HEIGHT

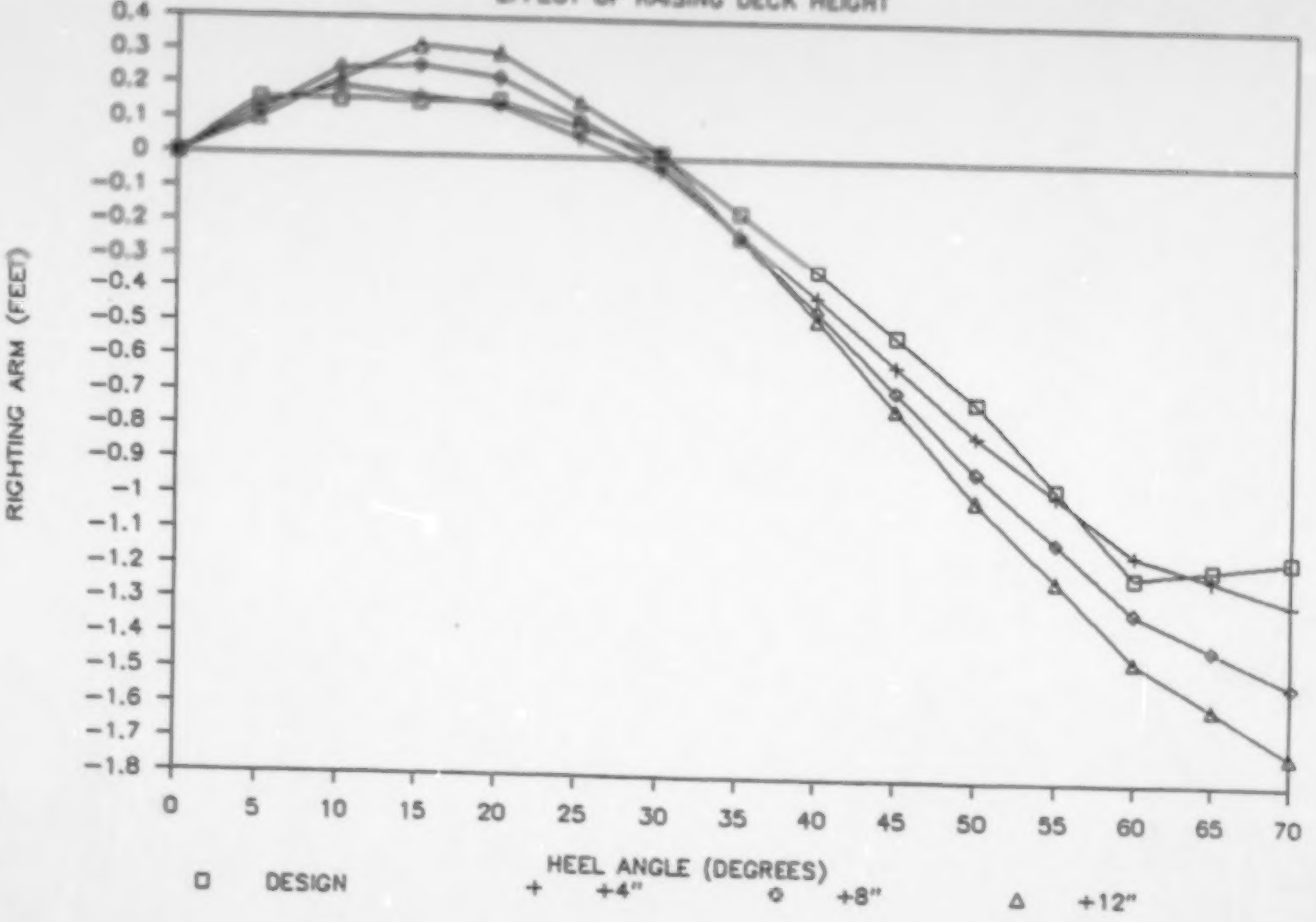
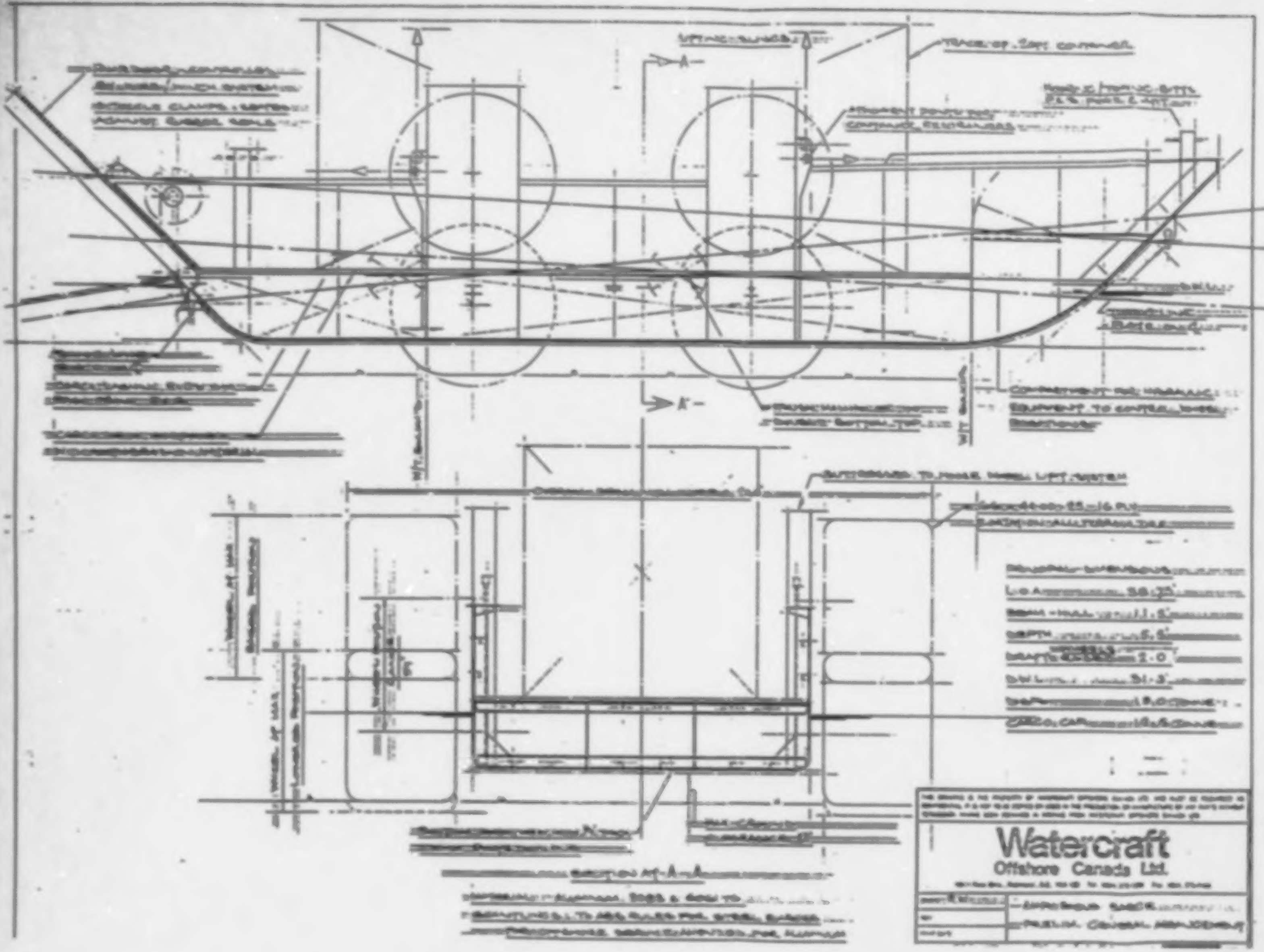


Diagram 1


Watercraft
Offshore Canada Ltd.
SECTION AT A-A
A
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BOW COMP. DAMAGED FLOATATION AT ℄

STERN ¼ COMP. DAMAGE FLOATATION AT SIDE

STERN ¼ COMP DAMAGE FLOATATION AT ℄

DAMAGED CONDITION

NO BUOYANCY MATERIAL

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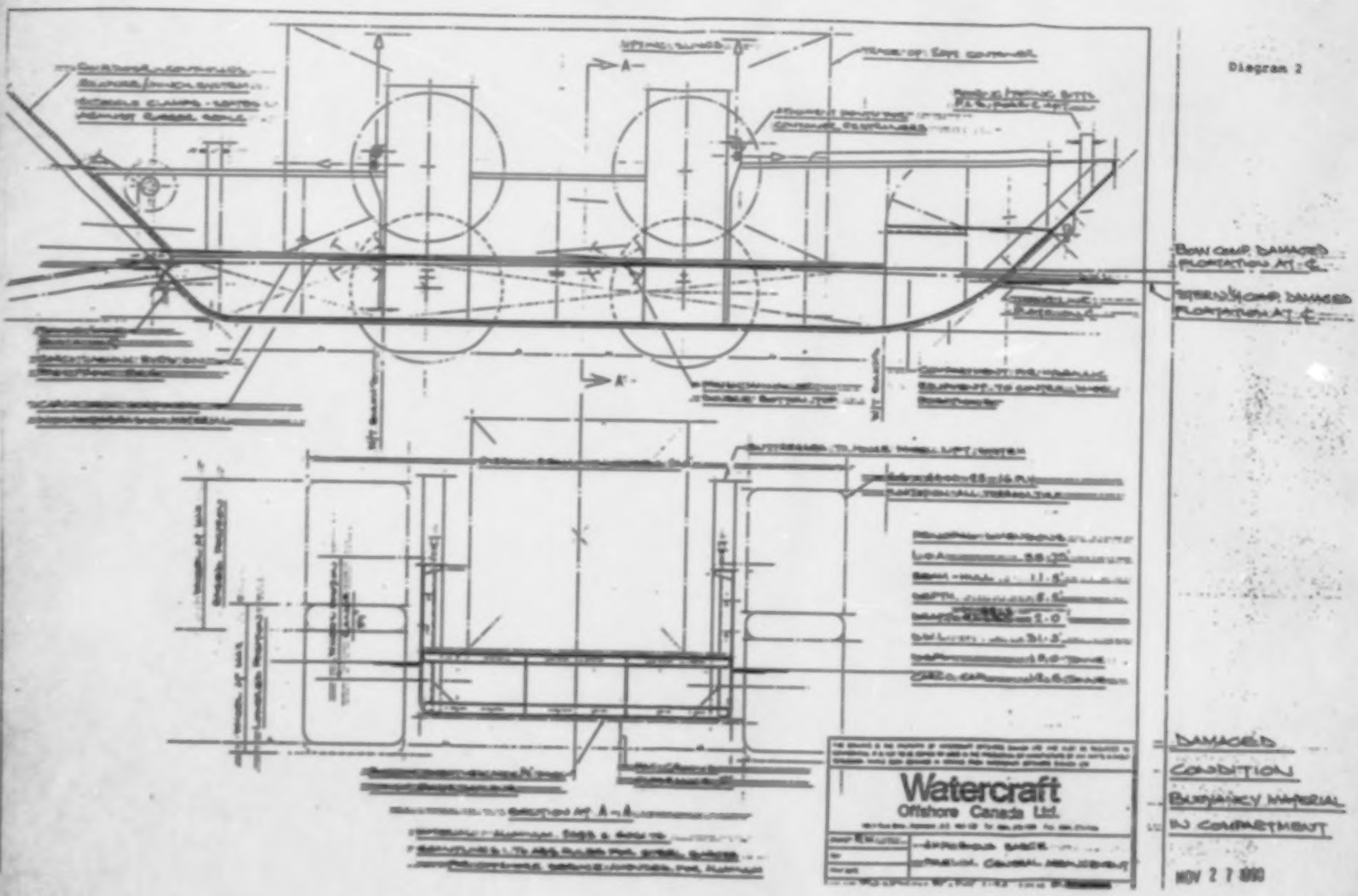
X

Diagram 2


BOW COMP. DAMAGED FLOTATION AT ℄
STERN ¼ COMP. DAMAGED FLOTATION AT ℄
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Watercraft
Offshore Canada Ltd.
DAMAGED CONDITION
BUOYANCY MATERIAL
IN COMPARTMENT

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APPENDIX VI

Gradeability
Watercraft Offshore Canada Ltd.

GRADABILITY CURVE EXPLANATORY NOTES

Two Gradability Curves (Grade v. Speed) have been plotted for the ARKTOS-PABS combination. The base data for the ARKTOS vehicle has been derived from previous field testing and the curves predict performance for the combination in first and second gear with wide open throttle.

In deriving these curves these assumptions have been made:

1. The barge is loaded with 22.5 tonnes of payload as required by the Steering Committee for operations over land.

2. The tractive coefficient of the ARKTOS vehicle is taken as 1.00. This is a function of the track design whereby the grouser points sink into the terrain being crossed, slipping is normally due to failure of the terrain.

3. The net tractive effort of the ARKTOS vehicle in first gear is 50,000 lbs. and in second gear 30,000 lbs. Field trials have shown the vehicle needs about 29,000 lbs. of net tractive effort to climb a 40° slope.

4. The barge is on its wheels. Rolling resistance has been taken as 300 lbs. per 1,000 lbs. Gross Vehicle Weight in mud and as 75 lbs. per 1,000 lbs. Gross Vehicle Weight in snow. See comparison with Model Test results in Appendix II.

The gradability predictions can be summarized as follows:

1. In first gear

   1.1 without the barge: infinite but obviously within the bulk modulus of the terrain being crossed.

   1.2 with loaded barge in 4 ins. of snow: 41 degrees
   1.3 with loaded barge in mud: 33 degrees.

2. In second gear

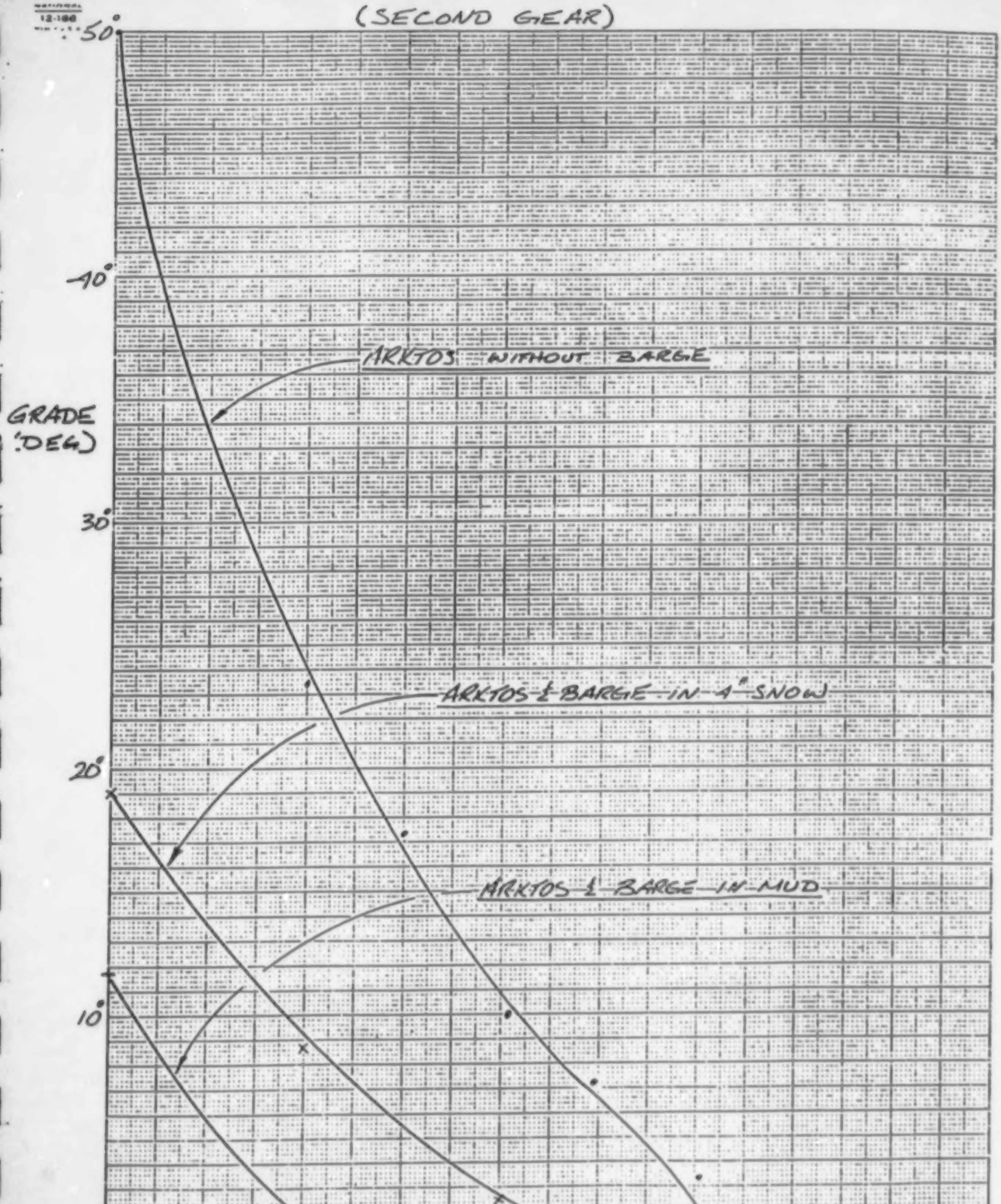
   2.1 without the barge: 50 degrees

   2.2 with loaded barge in 4ins of snow: 19 degrees

   2.3 with loaded barge in mud: 11.5 degrees.

Field trials would be the next stage to confirm or qualify these figures.

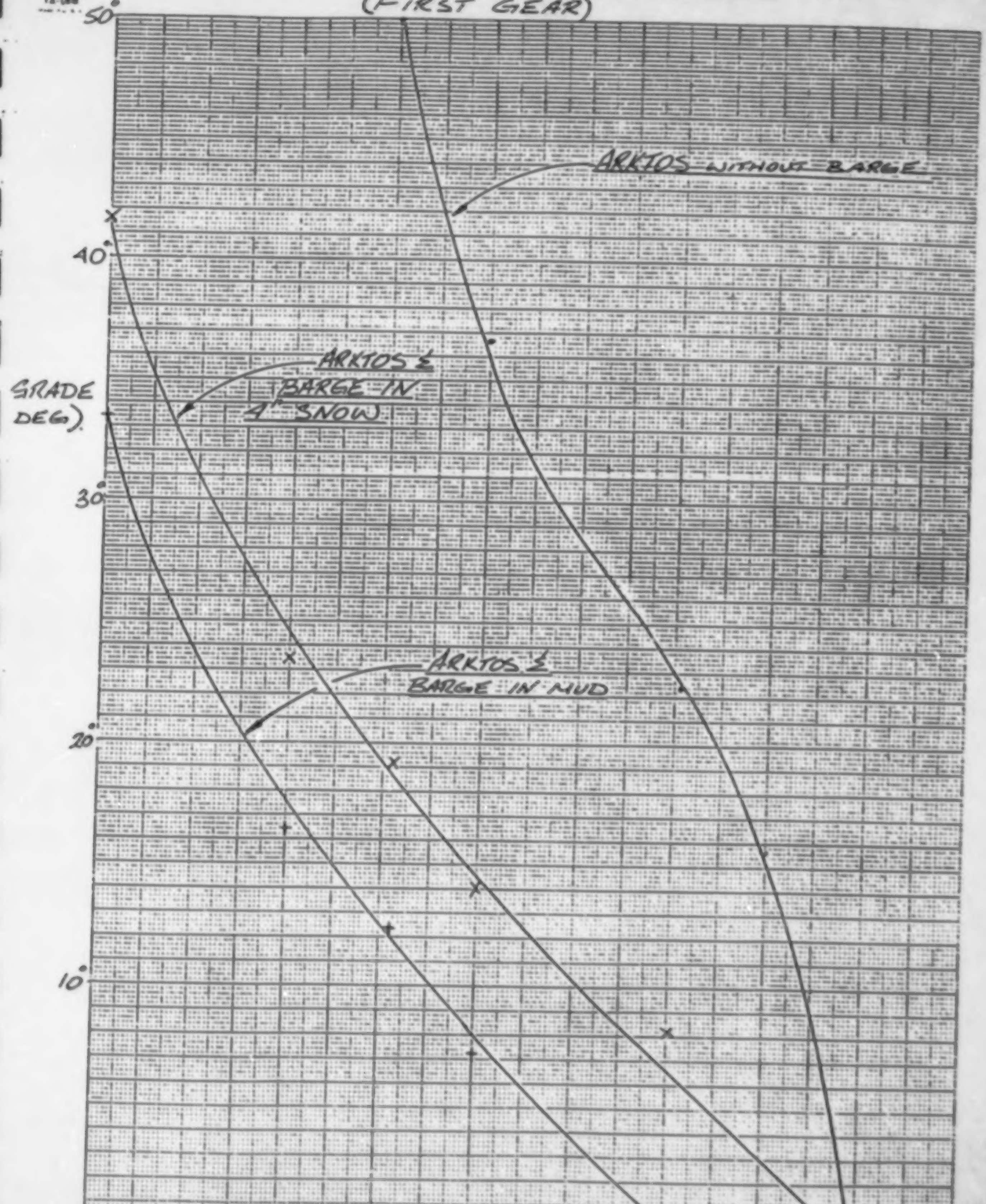
12-160



(SECOND GEAR)

10 Millimeters to the Centimeter

ARKTOS & HABS GRADABILITY
(FIRST GEAR)



10 Millimeters to the Centimeter